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SECURITY INFORMATION

MILITARY HYDROLOGY

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SECURITY INFORMATION

Corps of Engineers

Dept. of Army

Washington District

CONFIDENTIAL

SPECIAL STUDY S-51-4

WESER RIVER SYSTEM

HYDRAULIC EFFECTS OF DEMOLITION OF EDER DAM

VOLUME I

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WESER RIVER SYSTEM

HYDRAULIC EFFECTS OF DEMOLITION

OF EDER DAM

SECTION I. INTRODUCTION

1-01. ASSIGNMENT. This special study was assigned to the Military Hydrology R & D Branch, Engineering Division, Washington District, by letter from office of the Chief of Engineers, ENGWE to Division Engineer, North Atlantic Division, subject, "Military Hydrology, R & D Project No. 8-72-12-001: Special Assignments," dated 1 November 1951.

1-02. SCOPE OF THIS REPORT.

a. This report presents information regarding the hydraulic effects of possible demolition of the Eder Dam upon bridges and other structures along the Eder, Fulda and Weser Rivers and on the flood plains, and the changed potential of the river area as a military barrier subsequent to runoff of water released.

b. The report is designed to furnish basic data and results of analyses needed to answer questions concerning:

(1) Size of breaches and rates of discharge in dams and levees.

(2) Utilization of navigation structures and levee systems in conjunction with demolition of Eder Dam.

(3) Stages, discharges, velocities and time of travel of the artificial flood waves at key stations on the Eder, Fulda and Weser Rivers.

(4) Low, mean, and high stages, including duration, at key stations on the Fulda and Weser Rivers.

(5) Character of the stream bed materials and banks of the Weser River.

(6) Locations and elevations of zeros of gaging (pegel) stations.

(7) Reservoirs, navigation structures, levees and bridges on the Eder, Fulda, Diemel and Weser Rivers.

c. Additional studies are needed to adequately cover the subject for general military requirements.

1-03. ARRANGEMENT OF REPORT. This report is sub-divided as follows:

Volume I

1-04. DEFINITION OF TERMS.

a. Equivalent English-Metric Terms. Both the English and metric systems are involved in data contained herein. The following conversion factors are presented for convenient reference:

To reduce A to B, multiply A by F. To reduce B to A, multiply B by G

Unit A	Factor F	Factor G	Unit B
Miles (Mi.)	1.60935	.62137	Kilometers (Km.)
Meters (M)	3.2808	.30480	Feet (Ft.)
Meters	39.370	.025400	Inches
Cubic Meter (M^3)	35.3145	.028317	Cubic Feet (Cu.ft.)
Acre-feet	43560.	.000022957	Cubic Feet
Acre-feet (Ac-ft.)	1233.5	.00081071	Cubic Meters (M^3)
Second-feet (cfs)	1.9835	.50417	Acre-feet per 24 hrs.
Miles per hour	1.4667	.68182	Feet per second
Meters per second	3.2808	.30480	Feet per second
Meters per second	2.2369	.44704	Miles per hour

b. Selected hydrologic terms and abbreviations used in this report are given in Exhibit 1.

1-05. REFERENCES. All references cited herein by number are listed in the bibliography at the end of the report.

SECTION II

DRAINAGE BASIN CHARACTERISTICS & DEVELOPMENTS

2-01. GENERAL.

a. The Weser River is formed by the confluence of the Werra and Fulda Rivers, near Hann Muenden, each of which has its source in the hills of the Mid-German Highlands. The Weser River traverses the North German Plain, flowing from South to North to enter the North Sea near Bremerhaven. The course is extremely tortuous for most of the 478 km length. The major left bank tributaries are the Eder (which joins the Fulda near Gunterhausen), the Diemel, and the Hunte; the right bank tributaries are the Aller and Hamme Rivers. Maps are presented as Exhibits 2 and 3, and a detailed description is tabulated in Appendix A.

b. The information presented in this section is limited to consideration of the main stem of the Weser River, the portion of The Eder and Fulda Rivers below the Eder Dam, and the reaches of the Diemel River below the Diemel Dam.

2-02. DRAINAGE AREAS. Watershed lines of the major drainage basins of Germany are shown on Exhibit 3. The total drainage area of the Weser River and tributaries is 45,548 sq. km, which is 13 percent of the total area of post-war Germany. Following are tabulated drainage areas at key stations on the Weser River:

Station	River km	Drainage Area (Sq. km.)
Hann Muenden	0	12,460
Karlshafen	45	14,825
Hameln	135	17,113
Nienburg	268	21,891
Intschede	331	37,906

2-03. TOPOGRAPHY, GRADIENTS & CHANNEL PROFILES.

a. The topography of the Weser River basin is mountainous in the Upper Weser (Oberweser) above Porta. There the Middle Weser (Mittlere Weser) enters the North German Plain. The portion from the Hemelingen Weir to Bremerhaven, known as the Lower Weser (Unterweser) is tidal and flows through flat marshland. The Outer Weser (Ausserweser) below Bremerhaven consists of a wide estuary characterized by extensive sands and "watts"*, which are exposed only at low tide. The topography of the Weser River and its tributaries is indicated on the profiles presented on Exhibits 4 to 7, inclusive.

*Sandy marshland

b. The gradient in the Weser River varies considerably. Shallow stretches with very steep gradients alternate with deep stretches with very slight gradients. Navigation structures tend to equalize the gradient variations. The gradients of the Fulda, Eder, and Diemel rivers are generally steep, except where modified by navigation and water power dams. Average gradients are tabulated below:

Weser River	
Hann Muenden to Porta	4.7-3.2/10,000
Porta to Intschede	2.6-2.0/10,000
Fulda River	
Gunterhausen to Hann Muenden	5.4/10,000
Eder River	
Eder Dam to Gunterhausen	11.6/10,000
Diemel River	
Diemel Dam to Twiste River	23.2/10,000
Twiste River to Karlshafen	6.8/10,000

c. All elevations referred to herein are referenced to "Normal Null," (NN) the normal zero of the land horizon of the old Reich.

d. Official stationing along the Weser River is measured in kilometers downstream from Hann Muenden to Bremen, and is used herein for referencing profiles and locations. The tidal sections of the Weser River are measured downstream from Bremen. Profiles shown along the Fulda and Eder Rivers are measured upstream from Hann Muenden. However, for convenience, certain data are referenced in kilometers downstream from Eder Dam. Distances along the Diemel River are shown as kilometers downstream from the Diemel Dam.

2-04 CHANNEL CROSS-SECTIONS AND GEOLOGY.

a. Cross-Sections. The general character of the Weser River channel and valley is indicated by typical channel and valley cross-sections shown on Exhibits 8 to 12, inclusive. The cross-sections shown are fairly typical of the general stream characteristics in the vicinity of those locations, though considerable local variations can be expected. Additional cross-sections are contained in the document listed as Reference 1 in the Bibliography.

b. Nature of Stream Bed. The Weser River bed is firm and subject to but slight shifting. The bed from Hann Muenden to Minden is stony gravel, inclined to be rocky in certain locations. Below Liebenau the bed is composed of clay, becoming increasingly sandier to the mouth of the Aller River. Below that point the river bed is sand. Detailed description of the geologic conditions is presented in Appendix B.

2-05. CHANNEL AND FLOOD-PLAIN WIDTHS.

a. The channel width of the Weser River can be determined by reference to the typical channel cross-sections shown on Exhibits 8 and 9. The widths of valley subject to flooding can be estimated by reference to the general map, Exhibit 2, and to the typical valley cross-sections presented as Exhibits 10 to 12, inclusive. Accurate information regarding the natural flood plain as modified by the extensive system of local dikes and levees is not available. First-hand information should be obtained by local reconnaissance.

b. Following is a general indication of the widths of main channel and flood plain at various locations along the Weser River and its tributaries:

	Channel Width (meters)	Flood Plain Width (Kilometers)
Weser River		
Hann Muenden to Hameln	60-110	0.15- 2.6
Hameln to Porta	60-110	0.2 - 4.1
Porta to Nienburg	75-110	0.2 - 4.0
Nienburg to Mouth of Aller	75-110	4.2 - 21.3
Mouth of Aller to Bremen	110-150	9.0 - 20.0
Bremen to Bremerhaven	150-1800	9.0 - 22.0
Fulda River		
Gunterhausen to Hann Muenden	45-75	—
Eder River		
Eder Dam to Gunterhausen	25-45	0.5 - 1.6
Diemel River		
Diemel Dam to Marsberg	7.5-10.0	
Marsberg to Warburg	10.0-13.5	
Warburg to Karlshafen	15.0-30.0	0.8 - 3.0

2-06. CHANNEL DEPTH & TIDES

a. Upper & Middle Weser (non-tidal). The depth at mean low water (MNW), as augmented by regulated discharge from the Eder and Diemel Dams, varies from 1.1 to 1.6 meters. The depth at mean water varies from 2 to 3 meters. Reference is made to the stream profile on Exhibit 5 for detailed depth information.

b. Lower and Outer Weser (tidal). The tidal range between mean flood tide (MThw) and mean ebb tide (MTnw) of the Hemelingen Dam near Bremen was 3.0 meters for the period of record (1931-1935). The main navigation channel in the Lower Weser is designed to permit access up to Bremen of vessels of 8.0 m (26 ft.) draft at favorable water stages. Westerly winds tend to raise the water level, while easterly winds tend to lower it. The channel at Bremen is subject to considerable sediment deposition and dredging of the channel above Bremerhaven is necessary to maintain navigable depth. The mean and extreme depths are indicated on the profile, Exhibit 5.

c. Fulda, Eder and Diemel Rivers. The depth above the navigation dams on the Fulda River is 2.5 to 5.0 meters. Reference is made to the profiles shown on Exhibits 5 to 7, inclusive, for depths at specific locations. Following is a general indication of the average depths:

	Low Water (meters)	Mean Water (meters)
Fulda River		
Kassel to Hann Muenden	1.5	1.7-2.0
Eder River		
Eder Dam to Gunterhausen	0.4-0.5	0.7-1.2
Diemel River		
Diemel Dam to Karlshafen	0.2-0.9	0.5-1.5

2-07. NAVIGATION.

a. General. The Lower and Outer Weser River for the greater part of the time is navigable for sea-going vessels of maximum depth of 8.0 meters and capacity of 7,000 tons as far upstream as the Hemelingen Weir at Bremen. The Middle and Upper Weser River is not navigable at low water for fully loaded barges. The standard 1,000-ton barge fully loaded has a draft of about 2.0 meters, which exceeds the present augmented mean low water depth of 1.1 to 1.6 meters. This depth necessitates partial unloading of barges to navigate the Middle and Upper Weser during low flow conditions. Ultimate canalization to a project

depth of 2.3 meters is contemplated, but information is not available upon progress of that project. The Fulda River is theoretically navigable up to Kassel by 650-ton barges (drawing about 1.9 meters fully loaded). Reduced loads are resorted to during low summer stages. Above Kassel, the Fulda is classified as navigable by small barges as far upstream as Mecklar, but carries little traffic. Neither the Eder nor the Diemel River is navigable. Reference is made to Appendix A for detailed description of navigation structures.

b. Highest Navigable Water. The river stage above which navigation on the Weser is suspended for open river conditions under peacetime operation, designated as Highest Navigable Water (HSchW), is tabulated in Appendix A for certain critical locations. Those tabulated values approximate the line designated as Mean High Water on the profile of Exhibit 5.

c. Ice. The Weser River below Bremerhaven does not completely freeze over, nor does ice ever bank up in that part of the river. Between Bremerhaven and Bremen the navigation channels are kept open with ice breakers throughout the year. The Middle and Upper Weser River experiences ice for about 18 days between 25 December to 11 February during the average year but shipping is not usually hindered. Of 100 winters on the Weser River, 54 had no ice cover, 33 had ice cover once, 10 had ice cover twice, and only 3 had ice cover 3 times. The Fulda River often freezes in December and January to a thickness of 0.4 meters, but is always ice free by the end of March. The breakup of ice is not dangerous except at the confluence of the Eder River.

2-08. LOW WATER REGULATION.

a. Until recent times, the depths of the Middle and Upper Weser Rivers were too shallow to permit passage of barges during periods of low water. As part of an extended development plan drawn up in 1896, two storage reservoirs were constructed; the Eder Dam in 1914 and the Diemel Dam in 1924. The purpose of the reservoirs is:

(1) To augment the flow in the upper reaches of the Weser River during low water periods. Approximately 18 m^3/sec flow is available from the two reservoirs to augment the low water discharge, resulting in an increase in stage of about 0.35 m as far downstream as Minden, and about 0.15 m at the mouth of the Aller River.

(2) To replace water drawn from the Weser to feed the Mittelland Canal.

(3) To retain excess flood water in order to reduce flood stages on the Weser River.

b. Three navigation locks and dams are now provided to further regulate low stages at Hameln, Doerverden, and Hemelingen. Additional structures are proposed at: Petershagen, Schluesselburg, Landesbergen, Drakenburg, and Langwedel. Detailed information is lacking upon the progress of the project subsequent to 1938, at which time the Drakenburg, Petershagen, and Langwedel locks were in preliminary stages of construction. A number of navigation locks are located on the Fulda River, and several small water power dams are provided on the Eder and Diemel Rivers to regulate low water flow.

c. Locations of the control structures are indicated on the profiles of Exhibits 5 to 7, inclusive, and detailed descriptions are contained in Appendix A.

2-09. DAMS AND RESERVOIRS.

a. General. Descriptions of important dams on the Weser River and its tributaries are contained in Appendix A, and locations are indicated on the profiles of Exhibits 5, 6, and 7.

b. Eder River. The Eder Dam (Edertalsperre) is situated on the Eder River at Hemfurth, 49.2 kilometers above the confluence with the Fulda River. It is a multiple purpose reservoir providing storage for augmenting low flows on the Weser River, for control of floods on the Fulda and Weser Rivers, for water supply for the Mittelland Canal, and for power generation. Reference is made to Appendixes A and C for detailed description and to Exhibits 13 and 14 for sketches of the structure. The following pertinent data are presented:

Type - Rubble stone masonry gravity dam
Height - 48 meters
Total length - 400 meters
Spillway length - 152 meters
Top thickness - 6 meters
Base thickness - 35 meters
Storage capacity - 202 million cubic meters
Sluice capacity - 290 cubic meters per second

Associated with the Eder Dam are the auxiliary Peterskopf pump-storage reservoir and the Affoldern re-regulating reservoir. Several small dams, providing pondage for operation of mills and for local water supply, are located downstream from the Eder Dam.

c. Diemel River. The Diemel Dam (Diemeltalsperre) is located on the Diemel River near Helminghausen 85.3 kilometers upstream from the confluence with the Weser River at Karlshafen. Together with the Eder Dam, it provides for low water regulation of the Weser River, as well as for power generation. Reference is made to Appendix A for detailed description and to Exhibit 15 for cross-section of the structure. The following pertinent data are presented:

Type - Masonry gravity dam
Height - 41 meters
Length - 200 meters
Top thickness - 7 meters
Base thickness - 31 meters
Storage capacity - 20 million cubic meters

Associated with the diemel Dam is an auxiliary re-regulating reservoir downstream from the main structure. Several small dams for mill operation and local water supply are located below the Diemel Dam.

d. Fulda River. Nine locks and dams are located on the Fulda River between the mouth of the Eder River and the junction of the Fulda and Werra Rivers at Hann Muenden. The dams provide for navigation of the Fulda River and for operation of mills at the dam sites. Reference is made to Appendix A for detailed descriptions and to the profiles on Exhibit 5 for location of the dams.

e. Weser River. At the present time, locks and dams at Hameln, Doerverden, and Hemelingen provide storage for power generation and irrigation in addition to the primary purpose of navigation. The ultimate plan for canalization proposes five additional locks and dams as previously discussed in paragraph 2-08b. The Hameln Dam has a fixed crest weir, but the Doerverden and Hemelingen Dams have movable crests. Normally, the Hemelingen Weir is operated to maintain a stage above the dam of 4.50 m+NN during the summer (16 March to 14 November), and 5.50 m+NN during the winter (15 November to 15 March). Reference is made to Appendix A for detailed descriptions of the existing locks and dams.

f. Leine River. Although beyond the scope of this report, data regarding the two major dams located on tributaries of the Leine River are included as a matter of information for possible future consideration. These reservoirs are so far removed from the Weser that floodwaves originating at the dams would be small upon reaching the Weser River. The Oder Valley Dam is located north of Bad Lauterberg on the Oder River, which flows

into the Rhume, tributary to the Leine River near Northeim. The Soese Valley Dam is located north of Osterode on the Soese River, like-wise tributary to the Rhume River near the mouth of the Oder River. Both are multiple purpose reservoirs providing storage for flood protection, water supply, power generation, and flow regulation. Locations of the dams are shown on Exhibit 2. The following pertinent data are presented:

Oder Valley Dam

Type - earth dam of river gravel
Elevation, crest of dam - 383.00 m+NN
Elevation, foot of dam - 329.95 m+NN
Maximum water surface - 381.10 m+NN
Storage capacity - 30.6 million cubic meters

Soese Valley Dam

Type - earth dam of river gravel
Elevation, crest of dam - 328.50 m+NN
Elevation, foot of dam - 279.10 m+NN
Maximum water surface - 326.50 m+NN
Storage capacity - 24.45 million cubic meters

g. Werra River. Detailed descriptions of the navigation and power dams located on the Werra River are not presented as they are considered beyond the scope of this report.

h. Other Rivers. Numerous small navigation and water power dams are located on other tributaries of the Weser River but are not discussed as they are considered beyond the scope of this report.

2-10. LEVEES AND CANALS.

a. Levees. The banks of all the larger rivers of the Weser System are protected against erosion by groins, revetments and training walls as part of the canalization program. An extensive system of dikes and levees provides local flood protection to urban and agricultural areas along the flood plain. Data relative to the most important levees along the Weser River are presented on Exhibits 16 and 17.

b. Mittelland Canal. The Mittelland Canal System is the largest and most important of the German canals. It extends from Duisberg on the Rhine River to Magdeburg on the Elbe River. The course is shown on Exhibit 2. The Ems-Weser portion of the Mittelland Canal crosses over the Weser River at Minden by means of a canal aqueduct. Two short branches connect to

the Weser River at that point through locks. The main canal likewise crosses the Leine River by means of an aqueduct; while a branch, provided with locks, connects the river and canal. A diagrammatic map and a profile of the Mittelland Canal are presented on Exhibit 18 and standard canal cross-sections are shown on Exhibit 19.

c. Bruchhausen-Syke Canal. At Hoya, the Weser River is connected to the Bruchhausen-Syke (Meliorations Haupt) irrigation and drainage canal through an inlet lock constructed in the Weser dike. The lock includes three openings, each of 3.3 meters clear width. A second lock is located on the Main canal at Stapelshorn, 8 kilometers west of Hoya. That lock has a clear width of 12 meters and serves to close off the main canal in the event of dike failures and to raise the canal water level for irrigation of higher situated lands. Seven side canals branch from the main canal for distribution of irrigation water.

2-11. BRIDGES. Locations and clearances (wherever data are available) of major bridges across the Weser, Fulda, Eder and Diemel Rivers are indicated on the profiles of Exhibits 5, 6, and 7. Tabulations of pertinent bridge data are presented on Exhibits 20 to 25, inclusive. Reliable information upon post-war bridge reconstruction and modifications subsequent to 1945 is not presently available.

SECTION III

HYDROLOGY

3-01. GENERAL. Information regarding flood discharges, stage duration, observed water surface profiles, and surface velocities of the Weser River are presented in generalized graphical form insofar as practical in order to facilitate application of the data to specific military problems. References cited should be utilized for supplementary data.

3-02. CLIMATOLOGY. Annual precipitation in Germany ranges from 35 inches in the west to 24 inches in the east, with a national yearly average of 26 inches. The greatest precipitation falls during the summer. The water level of navigable streams fluctuates in response to seasonal and regional differences in rainfall. Low water interrupts navigation on all German rivers, while high water may at times give rise to serious floods. Detailed information is contained in the documents listed in the bibliography as References 2 and 4.

3-03. STREAM GAGING STATIONS. As an aid to navigation and to provide data necessary for hydrologic purposes, an extensive system of gages has been established on the Weser River and tributaries. Continuous or daily records are maintained at the more important gaging stations. Stage-discharge relations for key stations on the Fulda and Weser Rivers are presented on Exhibits 26, 27, and 28. Locations of gages of primary importance are indicated on the general map, Exhibit 2, and on the stream profiles of Exhibits 5, 6, and 7.

3-04. STAGES AND DISCHARGES.

a. Stages. Data regarding the maximum, mean, and minimum stages of record at various gaging stations on the Fulda and Weser Rivers are presented by months on Exhibits 29 to 32, inclusive, together with data pertaining to the gaging stations. Definitions of the hydrologic terms and abbreviations as presented on the exhibits and as commonly used in European literature are contained on Exhibit 1. Reference is made to the document listed as Reference 3 for detailed gage and stage data.

b. Discharge Rating Curves. Average stage-discharge rating curves for 11 key stream-gaging stations on the Weser and Fulda Rivers are presented on Exhibits 26, 27, and 28. The gage zero elevations, river kilometers with reference to Hann Muenden, mean water stage, 1926 high water stage, and stage of artificial floods analyzed in this report are also shown on the exhibits.

c. Discharge Records. Daily discharge records, monthly and annual averages and other pertinent data for the Weser River and tributaries are contained in the document listed as Reference 3 in the bibliography.

d. Seasonal Variations in Flood Stage. The maximum and minimum stages recorded during each month of the year at key stations on the Weser River are shown graphically on Exhibit 33. In order to permit convenient comparison of relative stages in successive months, stages equalled or exceeded 25, 50, and 75 percent of the time, respectively, are also indicated graphically. The period of record included in computations covers the 10 water years from 1926 through 1935. It may be observed that the magnitude and duration of flood stages at all stations are greatest during the winter month of January. The range of stages during the winter is much larger than during the summer months. It may be noted that the interquartile range (within the 25 to 75 percentage lines) becomes increasingly larger for the downstream stations, though for all stations is likewise generally larger during the winter than during the summer months. The seasonal operation of the Hemelingen weir is reflected in the graph for the Intschede gage, located 30.7 kilometers upstream of the weir.

e. Flood Crest Travel Time. Comparison of the recorded cresting time of the floods of January 1926, January 1938, and February 1946 indicates an average rate of progression of cresting time of natural floods as tabulated below:

Station	Average Travel Rate of Peak (km/hr)
Gunterhausen-Hann Muenden	5.6
Hann Muenden-Karlshafen	5.5
Karlshafen-Hameln	4.7
Hameln-Minden	3.7
Minden-Nienburg	2.9
Nienburg-Hoya	2.2
Hoya-Baden	2.9

3-05. STREAM VELOCITIES.

a. The velocity of stream flow varies according to the conformation of the river bottom, depths, obstructions and restrictions, local variation in slope, etc. Channel improvements and cutoffs, training walls and levees, operation of dams, and other man made

modifications of natural conditions appreciably affect the velocities. Influent rivers in flood tend to elevate the main river waters at the point of confluence according to the magnitude of the flood. This tends to reduce the slope above and increase it below the point of confluence. Accordingly, correlations between river stage at gaging stations and surface velocities cannot be interpreted as applicable to all points along the adjacent river sections, but only as general indications.

b. Available information regarding velocities at various points on the Weser River, against distance from Hann Muenden, between Hann Muenden and Bremen, are plotted on Exhibit 34. Velocity profiles are shown on this exhibit for the January 1926 high water and mean water. The velocities shown represent the estimated average surface velocities corresponding to the similar water surface profiles shown on Exhibit 5. Surface velocities were derived from crest stage and discharge records and cross-sectional areas at various typical locations. The deduced mean velocities were multiplied by 1.18 to obtain corresponding surface velocities. As stated above, it is to be expected that velocities greater or less than general values indicated by the velocity profiles may be expected at various points because of local channel and slope variations. Following are tabulated mean surface velocities at certain key locations taken from the profiles on Exhibit 34:

Location	River km.	Surface Velocities (ft/sec) Mean Water	1926 High Water
Hilwartshausen	3.6	3.3	5.5
Karlshafen	44.6	2.1	6.3
Bodenwerder	110.8	3.2	7.9
Hameln	135.6	1.9	6.2
Minden	203.2	2.9	8.9
Nienburg	267.7	3.1	6.7
Hoya	298.9	2.5	7.3
Intschede	331.2	2.0	6.3

SECTION IV

ARTIFICIAL FLOOD POTENTIALITIES

4-01. GENERAL.

a. The term "artificial flood" as used in this report applies to any major increase in the extent of flooding, over that normally prevailing with existing developments, that is brought about by manipulation of control structures, breaching of dams or levees, or temporary damming operations designed to create flooding conditions. The following three types of flooding were considered in this report:

(1) Still-water barriers, or drainage obstacles. In certain areas of flat topography, "still-water barriers" may be created by flooding land to form water obstacles or to reduce trafficability by admitting the water to the land through gates of canals, breaches in levees, or by similar means.

(2) Streamflow variations, in which sudden changes in discharges, depths, velocities, widths of streams are brought about to increase difficulties of stream crossing operations, such as might be accomplished by opening and closing large flood gates intermittently to create cyclical flood waves for limited distances downstream.

(3) Major flood waves, which may be caused by the sudden breaching of a high dam to release large quantities of impounded water.

b. Many opportunities exist for the effective use of the above three types of artificial flooding in the Weser River basin, and all three methods should be fully considered in the planning of military operations. This report deals principally with a "major flood wave" caused by breaching the Eder Dam; however, certain quantitative evaluations of the effects of breaching the Diemel Dam and controlled manipulation of the regulating gates of the Eder and Diemel Dams are also presented. The following paragraphs also review the possibilities of creating "still-water barriers," "streamflow variations" and "major flood waves" on the main stem of the Weser River, and present certain data regarding the manipulation of the regulating gates or demolition of existing dams and canals on the Fulda and Weser Rivers.

4-02. ARTIFICIAL FLOODING POTENTIALITIES OF NAVIGATION DAMS LOCATED ON THE FULDA AND WESER RIVERS.

a. General. The studies reviewed in this paragraph pertain to the use of the navigation dams and levees on the Fulda and Weser Rivers to create artificial flooding. A large part of the information summarized hereinafter is obtained from Reference 5. Reference is also made to Appendix A for more detailed information.

b. Means of Creating Artificial Flooding. The navigation dams, levees and bridges on the Fulda and Weser Rivers provide at least five methods by which artificial flooding could be created to make the Weser River a more effective military barrier:

(1) Flood waves created by demolition of navigation dams.

(2) Flood waves created by regulation of control gates of navigation dams.

(3) Inundation of lowlands by raising crest gates of navigation dams to maximum height.

(4) Inundation of lowlands by installation of auxiliary barriers at key points such as bridges.

(5) Inundation of lowlands by breaching dikes and levees.

c. Utilization of Navigation Structures on the Fulda and Weser Rivers for Military Purposes.

(1) By raising the gates of the Hersfeld Fulda Weir located at the confluence of the Fulda and Haune Rivers, approximately 30 centimeters and closing the gates at the power plant and Haune-Bingartes Mill, water can be diverted through the irrigation facilities at Haune-Muehlengraben and cause flooding of approximately 3/4 square kilometers of valley. By rapidly opening the gates at the weir and releasing approximately 135,000 m^3 of water, an abrupt wave can be released. This could be repeated approximately every 3 hours which is the time required to refill the storage pool at medium flow.

(2) By use of the roller dam at Kassel (km 75.5), the flood plain upstream on the right bank below the railroad bridge at Waldkappele (km 80) and Karlsaue can be temporarily flooded at medium flow (MW). Overbank flooding occurs at +4.00 m on the gage at Gunterhausen

(15 kilometers above Kassel). This corresponds to a discharge of 470 m^3/sec.

(3) Since the dam at Hameln (km 135.3) has a fixed crest, raising of the upper pool is not practical. No military use could be made of the Hameln weir.

(4) By completely closing the gates of the Doerverden Weir (km 308.8) the pool stage can be raised 0.50 meters over the normal stage of NN+15.10 meters. This would cause flooding of the valley within the winter dikes up to Hoya (km 300) with resultant damage to agricultural land. An abrupt wave can be created by completely opening the gates. This can be repeated every 2 or 3 days by completely shutting off the power station and navigation.

(5) Through the complete closing of the Hemelingen Weir (km 362.0) above Bremen, the valley within the dikes can be flooded within an area of about 30 square kilometers, bounded by Hemelingen, Mahndorf, Dreye and Bollen. The breaching of dikes at high water is particularly effective on the left bank above Habenhausen (kilometer 360.0) up to Dreye. This would flood an additional area of about 20 square kilometers in the Ochtum Depression between Brinkum, Arsten and Bremen-Neuenlande. The flooded area would be about 10 kilometers in length and the operation would require approximately one week with a continuous flow of 100 m^3/sec passing through the dike sections. By raising the gates during the winter and shutting down the turbines, the pool can be raised to 6.20m+NN. This causes flooding of the banks of the upper pool and creates a considerable obstacle.

(6) The release of a large volume of water from the Hemelingen Weir to create an abrupt flood wave would disrupt navigation upstream, shut down the power plant, and would cause minor damage to the river banks and the city of Bremen immediately downstream. Below Bremen, however, the wave would not be effective because it enters a wide channel which is subject to tidewater.

(7) In the lower Weser (below Bremen) it is possible to flood the large marsh and depression regions to varying degrees by breaching the dikes. The depth of flooding will depend particularly on the difference in elevation between the mean water stage (see profile, Exhibit 5) and the elevation of the adjoining terrain. Factors

affecting the stage are the losses from storage in culverts, ditches, and sluices; also seepage and evaporation. The temporary drop of high tide stages due to east winds is also important to consider. Reverse effects occur from runoff of the uplands which flow into the depressions, particularly in the winter time. Considering all the circumstances, the depressions generally can be filled approximately 50 centimeters below the existing stage in the river. Several days will be required to produce effective flooding of the area either by opening the flood gates or breaching the dikes.

4-03. ARTIFICIAL FLOODING POTENTIALITIES OF CANALS.

a. General. Reference is made to paragraph 2-10 and to the document listed in bibliography as Reference 2 for a detailed description of the canals.

b. Mittelland Canal.

(1) Demolition of the Mittelland Canal (Ems Weser-Weser Elbe) aqueduct at Minden would empty the water stored in the canal (approximately 17 million m^3) into the Weser River, provided the canal safety gates were raised (see Exhibit 18). The rate of flow from the canal, however, would be so slow that this operation would not create an effective artificial flood on the Weser River below Minden. Approximately 5 million m^3 would be discharged in 48 hours, and several weeks would be required to drain the remaining water in storage. The rate of discharge is indicated in the tabulation below:

Average Discharge m^3/sec	Start of Discharge Hour	End of Discharge Hour	Duration hours
150	0	0.5	0.5
100	0.5	2.0	1.5
50	2.0	7.0	5.0
35	7.0	15.0	8.0
25	15.0	30.0	15.0
15	30.0	48.0	18.0

(2) The water in the canal could also be diverted into tributaries of the Weser River. Breaching the canal where it crosses the Aue, Weser, Leine, Oker and Aller Rivers (see General Map Exhibit 2) would drain it more quickly than demolition of the aqueduct. The water

would eventually flow into the Weser below the mouth of the Aller River; however, there would be no appreciable flooding on the tributaries and there would be no appreciable increase in stage on the Weser River.

c. Bruchhausen-Syke Canal. Preliminary investigation indicated that it might be possible to divert part of the flow of the Weser River into the Ochtum Depression area through the Bruchhausen-Syke irrigation canal at Hoya by raising the Doerverden Weir gates and opening the canal gates. This flooding operation will be quite slow since the capacity of the canal is relatively small. With a carefully conceived plan, it is estimated that it would require from two to three weeks, depending upon the flow diverted from the Weser, to accomplish a successful flooding operation. Further detailed investigation may show that this diversion operation might be done more effectively by construction of temporary barriers at certain points on the Weser River; for example, one of the two bridges at Hoya. The latter study is considered beyond the scope of this report.

4-04. ARTIFICIAL FLOODING POTENTIALITIES OF DAMS LOCATED ON THE HEADWATERS.

a. General.

(1) The studies reviewed in this paragraph pertain to the artificial flooding effects that might be produced by regulation or breaching of the Eder and Diemel Dams.

(2) The bombing of the Moehne, Sorpe and Eder Dams by the R.A.F., in May 1943 provides the basis for estimating the size and shape of breach that could be made by demolition. For a detailed description of the results of the attack, reference is made to the document listed as Reference 6 in the bibliography, a translation is inclosed as Appendix C of this report.

(3) Since both the Eder and Diemel Dams are gravity, rubble-masonry structures, and have approximately the same height and thickness (see paragraph 2-09 for description), it was assumed that demolition would cause a breach in the Diemel Dam similar to the one in the Eder Dam; therefore, the reference numbers assigned to the various size breaches described in this paragraph apply to both dams.

(4) The information summarized hereinafter that pertains to gate regulation of the two reservoirs has been obtained from Reference 5. Observed stages and discharges of the flood wave created by the May 1943 breaching are from Reference 1.

b. Hydrologic Considerations.

(1) The natural discharge of the Fulda and Weser Rivers normally is not disturbed by operation of the dams for power, because of the re-regulation pools immediately below the Eder and Diemel Dams. During low flow periods, however, navigable stages are maintained by releasing the water from storage in the two reservoirs.

(2) The hydrologic conditions, discussed in the following paragraphs, that influence possible artificial flooding are initial reservoir pool level and base flow.

c. Means of Creating Artificial Flood Waves. The Eder and Diemel Reservoirs each provide two methods by which artificial flood waves could be created to increase the effectiveness of the Weser River as a military obstacle:

(1) Breaching the Eder Dam would cause the greatest possible artificial flood on the Eder and Weser Rivers. The greatest artificial flood on the Diemel River likewise would be caused by breaching the Diemel Dam. The latter flood could be used to support the flood wave from the Eder when it reached the confluence of the Diemel and Weser Rivers at Karlshafen.

(2) By alternately opening and closing the control gates of the two dams, a series of lesser flood waves could be sent down the Eder and Diemel Rivers. The number of days that cyclic waves could be generated would depend chiefly upon the quantity of water stored in the reservoirs at the time. As in the case of breaching, the flood waves from the Diemel Dam could support the flood waves from the Eder.

d. Effects of Breaching the Eder and Diemel River Dams.

(1) Breaching Operations.

Breaching operation No. 1 was assumed to be the same as the actual breach caused by the bombing attack of May 1943. Available information gives only approximate dimensions of the opening. Exhibit 13 shows the repair line after

the breach was closed. The repair line is probably larger than the original breach because loose and broken sections had to be removed during reconstruction. The discharge capacities of variously shaped breaches were compared with observed data for reservoir draw-down after breaching. The estimated control section of the opening is indicated by a broken line on Exhibits 13 and 14. Breaching Operation No. 2 was assumed to be two openings, each of which were the same as Breach No. 1, or an equivalent opening having twice the capacity of Breach No. 1.

Breaching Operation No. 3. In order to reduce overbank losses in the headwater areas, a discharge hydrograph was computed for an opening made by progressive breaching in the following manner:

(a) Initial Breach to give one-half the discharge of Breach No. 1 (4000 m^3/s)

(b) Followed by second breach same as (a) when discharge recedes to 2000 m^3/s

(c) Followed by third breach same as Breach No. 1 at time when the three breaches will discharge a total of 4000 m^3/s

(2) The breach-rating curves for Breaching Operations Nos. 1, 2, and 3 are shown on Exhibit 35.

(3) The reservoir storage curve for the Eder Dam is from Reference 1 and is shown on Exhibit No. 35. A storage curve for the Diemel Reservoir was not available. The curve shown on Exhibit 35 was developed by the method presented in "A Progress Report on the Disposition of Sediment in Reservoirs" by A. W. Van't. Hul. (See Reference 7)

The equation of the computed storage curve for the Diemel Dam is:

$$S = 945\ h^{2.82}$$

where S = storage in cubic meters

h = reservoir depth in meters

(4) Artificial Flood No. 1 is the flood wave on the Eder and Weser Rivers caused by Breaching Operation No. 1 in Eder Dam, and is shown on Exhibits 36, 37, and 38. The outflow hydrograph at the dam was computed from the storage-discharge relationship and routed downstream to the mouth of the Eder (Gunterhausen gage). The peak discharge of 8500 m^3/sec at the dam is reduced to 2450 m^3/sec at Gunterhausen. Estimated surface velocities at various stations on the Weser River resulting from the breaching of May 1943 are tabulated below. For comparison with the surface velocities for mean water (MW) and the 1926 flood, reference is made to paragraph 3-05b and to Exhibit 34.

Location	Surface Velocities (ft/sec)
Hilwartshausen	7.0
Karlshafen	7.2
Bodenwerder	7.9
Hameln	5.9
Minden	6.7
Nienburg	3.6
Hoya	4.2
Intschede	3.0

(5) Artificial Flood No. 2 hydrograph results from Breaching Operations No. 1 in the Diemel Dam and is shown on Exhibit 39. The peak discharge is reduced from 8500 m^3/sec at the dam to 480 m^3/sec at the mouth (Karlshafen gage). Since this flood has only one-tenth the volume of that of the Eder, the peak reduction takes place at a greater rate than for the Eder flood.

(6) Artificial Flood No. 3 is caused by Breaching Operation No. 2 in the Eder Dam. The peak discharge decreases from 17000 m^3/sec at the dam to 3200 m^3/sec at Gunterhausen. (See Exhibit 36)

(7) Artificial Flood No. 4 is the flood wave on the Diemel River that results from Breaching Operation No. 2 in the Diemel Dam. (See Exhibit 39) The peak discharge is reduced from 17000 m^3/sec at the dam to 500 m^3/sec at the mouth (Karlshafen).

(8) Artificial Flood No. 5 would be created by Breaching Operation No. 3 (progressive breaching) in Eder Dam. The hydrograph at the Eder Dam (see Exhibit 36), has three peaks of 4000 m^3/sec each about 5 hours apart and is reduced to a single peak of 2200 m^3/sec 16 hours after time of demolition. Since the peak of this flood

is lower and later than that of Floods 1 and 3, the flood hydrograph resulting from Breach No. 3 at the Diemel Dam was not developed.

(9) Artificial Flood No. 6 is created by the simultaneous breaching of both dams, using Breaching Operation No. 2 at the Eder Dam and Breaching Operation No. 1 at the Diemel Dam. The effects on the Eder and Diemel basins are the same as Flood No. 1 on the Eder River and Flood No. 2 on the Diemel River. The increase in discharge at key stations on the Weser River over that of Flood 1 are indicated on Exhibit 40.

(10) Comparison of Artificial Floods. The stages, discharges and travel times for Floods 1 through 6, inclusive, are tabulated on Exhibit 40.

(11) Effect of Non-synchronous Breaching. It is to be noted in considering Floods 2, 3 and 4 on Exhibit 39 that, assuming simultaneous breaching of both dams, the Diemel hydrograph peaks at Karlshafen approximately 12 hours before the Eder hydrograph. If the Diemel breaching occurs 9 to 15 hours after the Eder breaching, the peaks will combine at Karlshafen producing a peak flow of 2900 m^3/sec, which is an increase of 450 m^3/sec over that of Flood 2 at Karlshafen (2900 m^3/sec-2450 m^3/sec).

e. Effects of Gate Regulation of Eder and Diemel River Dams.

(1) The main outlet works of Eder Dam are designed to discharge a maximum of 230 m^3/sec. Since the lower Eder overflows the banks at 190 m^3/sec, it is possible to create floods by gate operation. When the reservoir is full, the maximum discharge of 230 m^3/sec would decrease to 190 m^3/sec in 6 days. To sustain a flow of 190 m^3/sec, it is necessary to maintain the reservoir pool at elevation 233 m.NN.

In order to release 230 m^3/sec, all 6 low level outlets at the right side of the dam must be opened and all six turbines must run at full gate opening. In addition all gates of the Affoldern Weir must be raised simultaneously.

In order to release more than 230 m^3/sec, the emergency outlets located at the upper third point of the dam can be opened. This will increase the flow to 290 m^3/sec, which will gradually diminish to 190 m^3/sec in 5 days.

A large release from Eder Dam was experimentally tested in 1929. This release had a base of 84 hours (24 hours rise, 24 hours uniform flow of 60 m^3/sec and a 36-hour

recession) which was used to refloat a number of vessels. The effects of this wave are given as follows:

	Dam	Hann Muenden	Hameln	Minden	Hoya
Distance from Dam in km	0	90	225	295	389
Travel time of the crest, hours	0	22	52	60	76-1/2
Duration of wave in hours from start of rise to full recession	84	88-1/2	81-1/2	84	87-1/2
Rise in cm	—	60	50	40	30

In the above case, the effect of the wave depends also on the base flow of the Weser. The velocity of the wave will increase with increase in base flow. Extreme flooding on the Fulda occurs at a flow of 470 m^3/sec. In order to cause such a flow, the 230 m^3/sec release from the Eder would have to be made at a time when the Fulda was carrying a flow of at least 240 m^3/sec which occurs greater than 2 percent of the time. At MW flow on the Fulda (150 m^3/sec) a release of 230 m^3/sec, however, would cause a considerably high stage.

The Affoldern Re-regulating reservoir (capacity 3.8 million m^3) can be used by itself when the Eder Lake is low to create a very effective flood wave of 900 m^3/sec for a short duration. When storage is available in the Eder Reservoir, the operation can be repeated by refilling the Affoldern Reservoir.

(2) By means of low level outlets, is is possible to release 60 m^3/sec from the Diemel Dam. This could be used to support a simultaneous release from Eder Dam. The right outlet of Diemel Dam can be opened without difficulty. The left outlet, however, is normally locked and is more difficult to open. During this operation, the turbine penstocks should be closed.

The Diemel River overflows at a discharge of 12 m^3/sec so that by releases from the dam flood waves could be produced and maintained for a period of time

depending on the water in storage. By a sudden release from the re-regulating reservoir a flow of 114 m^3/sec can be obtained causing a flood wave of short duration.

f. **Conclusions.**

The following conclusions are derived from this investigation:

(1) The May 1943 breaching of the Eder Dam caused major destruction in the Eder Valley. The flood wave washed out the retaining dike of the re-regulating pool and heavily damaged the power stations at Hemforth and Affoldern. The locks of seven of the dams on the Fulda between Gunterhausen and Hann Muenden were silted in, and the weirs and gates severely damaged. The flood wave caused extreme scouring immediately below the dam and shoals were formed by the sediment movement as far downstream as Hann Muenden. It was then necessary to remove these shoals by dredging before navigation could be resumed on the Fulda and Weser Rivers. The dikes on the upper Weser and Fulda Rivers were also severely damaged. The surface velocities of Flood No. 1 below Hann Muenden to Hemelingen Weir are indicated on Exhibit 34.

(2) Artificial Floods 1, 3 and 6 would destroy or damage most bridges on the Eder River down to the vicinity of Gensungen (35.0 kilometers below dam). From Gensungen to the mouth of the Eder no certain estimate can be given. On the Fulda River below the mouth of the Eder, bridges down to the vicinity of Kassel may be damaged (especially from Artificial Flood No. 3). Below Kassel, bridge damage would probably be slight, but some foundations might be weakened by scouring action. An estimate of damage to bridges on the Eder River as a result of breaching the Eder Dam are indicated in the following tabulation:

Km from Eder Dam	Name and Location	Type	Remarks
2.0	Hemfurth	Road	Completely destroyed
2.3	Hemfurth	Railroad	Completely destroyed
6.5	Affoldern	Road	Completely destroyed
7.0	Mehlen (Affoldern)	Road	Completely destroyed
9.0	Bergheim	Railroad	Completely destroyed
10.0	Bergheim	Road	Completely destroyed
12.0	Anraff	Road	Probably damaged
14.0	Wega	Road	Completely destroyed
16.0	Mandern	Road	Damaged & approaches destroyed
22.0	Fritzlar	Road	Probably damaged & approaches flooded
25.0	Obermoellrich	Road	Completely destroyed
28.0	Niedermoellrich	Road	Probably slightly damaged
29.8	Lohre	Road	Probably slightly damaged
35.0	Gensungen	Road	Probably slightly damaged

(3) On the Diemel River, no certain estimate can be given, but the bridges within 20 kilometers of the dam would probably be destroyed or damaged by Flood Nos. 2 or 4. Below this point to the mouth, scouring would weaken some bridge foundations.

(4) Artificial Flood No. 6 would produce the maximum damaging effect of the floods considered. Larger breaches which would completely demolish the Eder and Diemel Dams would not cause stages appreciably higher than Artificial Flood No. 6 on the Weser River below Minden.

(5) The elevation of the reservoir pool at the time of demolition will have a direct bearing on the rate of discharge of the water through the breach. This relationship is shown by the rating curve on Exhibit 35. For example, at the time of the May 1943 attack, the Eder Reservoir was at elevation 244 m+NN, and the peak rate of flow through the breach (No. 1) was 8500 m^3/sec. If the pool had been, at say, elevation 235 m+NN, the peak of the outflow hydrograph with the same size breach would have been 2100 m^3/sec and the effect downstream would have been reduced accordingly. The storage available in the two reservoirs is dependent upon the time of the year. In general, the reservoirs are replenished during the winter and spring months until filled in May, and then drawn down during the summer. It is to be noted that the Eder Dam was bombed in May when the reservoir pool was one meter below the spillway crest.

(6) The amount of flooding to be expected in the rivers downstream from Eder Dam depends upon the flow of water, or base flow, existing at the time prior to the flood wave. To find the stage to be expected from an artificial flood when the river at a key station is at a given stage, reference is made to Exhibits 26, 27, 28, and 40. Add the difference in the base flows between that indicated on Exhibit 40 and the flow for the given stage to the peak discharge of the flood shown on Exhibit 40. Having determined the new peak discharge, determine the new stage from the rating curve for the station in question.

(7) The levees and navigation dams on the Weser River can be utilized to increase the effectiveness of artificial floods caused by breaching Eder Dam. The elevations, widths, and time of overbank flooding for Flood No. 1 are tabulated in Exhibit 41 for 2 conditions; levees intact and levees breached. Consideration was also given t the effect of the Doerverden and Hemelingen weir gates in both lowered and raised positions. Raising the gates increases the water surface elevation approximately 1.5 meters at the weir and 1.1 meters at Bollen with a flow of 400 cubic meters per second.

(NOTE: During the May 1943 breaching, the weirs were lowered to reduce the peak stage). Flood No. 2 would increase the peak elevation approximately 0.5 meters. Where 0.05 kilometer widths are indicated, the flow is confined within the banks, with some flooding of very low-lying bottom lands immediately adjacent to the river.

(8) Flooding of the Ochtum Depression was considered in connection with Floods 1 and 6 by raising the Hemelingen Weir to elevation 5.5 m+NN and breaching the levees in the low areas along the left banks in the vicinity of Arsten. The extent of flooding would depend upon the size and depth of the breach. In the passage of a flood wave such as for Floods 1 or 6, a large part of the discharge would pass over the Hemelingen Weir and across the low ground to the left of the weir structure. Since the flood peak is of relatively short duration only a fractional part of the volume could be diverted to the Ochtum Depression. Even though this diversion be accomplished the flow would pass to the sea unless barriers were established and gate closures were made within the area. If it is assumed that a breach be made in the levee equivalent to 25 meters length with the base of opening at elevation 5+m+NN, less than 20 percent of the volume for Floods 1 or 6 could be diverted. The diversion to the area would flood about 20 square kilometers with the construction of necessary barriers. The velocity accompanying the passage of flow through the levee breach would result in very little scour.

(9) If regulated flood waves or a sustained flow of 230 m^3/sec were released from the Eder reservoir by gate regulation, the duration of overbank flooding in the Hemelingen pool areas would be increased over that caused by breaching and a greater volume of the water could be diverted to the Ochtum Depression. The river stages obtained in the Hemelingen pool would be somewhat lower and it would require a longer time to flood the Ochtum Depression.

(10) By means of artificial floods created by the methods discussed in this section of the report, the Eder, Fulda and Weser Rivers could, in conjunction with a complete bridge demolition program, present a continuous obstacle, for a limited time, to military movements which do not have the aid of special bridging operations or amphibious devices.

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Reference Number	Document
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LIST OF EXHIBITS

APPENDIX A

*Abstracted from "Stromgebiet der Weser und Ems, Einwirkung auf die Wasserfuehrung," Military Geography Training Manual H. Dv. g. 33a, prepared by General Staff of German Army, December 1937.

DESCRIPTION OF WATERCOURSE

Basin: Weser-Ems
River: WESER

All information refers to river reaches and adjacent regions and indicates the important characteristics.
The order of listing in columns 1 and 2 is in downstream sequence.

River km	Place Watercourse stretch resp.	Sheet No. Obj. No.	Average Width m	Average Tow depth m	NNW El. over NN	MNW El. over NN	MNW Dis-charge cbm/sec	MNW Max. velo-city m/sec	MW El. over NN	MW Dis-charge cbm/sec	MW Max. velo-city m/sec	HSchW El. over NN	HSchW Dis-charge cbm/sec	HSchW Max. velo-city m/sec	HHW El. over NN	Supplementary Information a. Riverbed and Channel b. Banks and Floodplain c. Remarks (Col. 17-19)
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
0.0	Hann Muenden				115.53	116.0			117.0			119.8			124.11	b. Steep banks along a few reaches. Width of flooded area varies, but covers entire flood plain at HW. Some overbank areas are not flooded until approx. MW. Short dead channels on right bank above GIESELWERDER.
	Open River		50	1.84			30	1.0		96	1.5		490	2.2		
130.0	Upper Limit of Hameln pool				63.58	63.97			64.47			66.64			69.51	
	Pool condition		100	3.0			51			132			620	2.4		
	Headwater					63.7			64.14			64.42			67.7	
135.3	Hameln Weir	83/73		(Weir crest)												a. Km 182.5-183.0: Sandstone reef across streambed
	Tailwater				59.74	60.49			61.58			64.42			67.7	
	Open River		60	3.1			56	1.0		142	1.4		630	2.4		b. Floodplain extends as far as high rim of valley plain.
190.15	Werre River Mouth				40.43				40.99			44.92			47.43	a. Km 202.5-203.0, 206.0-209.0: Rocky clayslate subsurface.
	Open River		70	2.5-3.5			68	1.1		172	1.5		640	2.1		b. Banks generally flat, in some places as high as 3m above "elevated middle low water" (E.M.Kl.W.). Dikes extend down-stream from OVENSTADT, Km 220.
287.0	Upper Limit of Doerverden pool				14.70	15.26			16.32			19.43			21.42	
	Pool condition		100	4.3-6.3			77			188			640	2.1		a. River bed and banks covered by slimy sediment below DOERVERDEN WEIR.
	Headwater				14.6	14.6			14.6							
306.85	Doerverden Weir	80/47			(Normal stage)											b. Floodplain as wide as 17.5 km in places, limited by dikes or high embankments, "Geestraender." Large dead channels: on left bank opposite LANDESBERGEN, opposite NIENBURG (DUERSTERE LAKE); on right bank at ESTORF, at km 263.5. Between km 292-297 on right bank is a small depression with small dead channels.
	Tailwater				9.76	10.82			11.97			15.27			16.2	c. Km 29?; junction of MELIORATION Canal, which provides up to 3? cbm/sec irrigation flow to BRUCHHAUSEN-SYKE THEDINGHAUSEN Region.

*General Map Reference

DESCRIPTION OF WATERCOURSE

Basin: Weser-Em
River: Weser

All information refers to river reaches and adjacent regions and indicates the important characteristics.
The order of listing in columns 1 and 2 is in downstream sequence.

River km	Place Watercourse stretch resp.	Sheet No.* Obj. No.	Average Width m	Average Low depth m	NNW El. over NN	MNW El. over NN	MNW Discharge cbm/sec	MNW Max. velocity m/sec	MW El. over NN	MW Discharge cbm/sec	MW Max. velocity m/sec	HSchW El. over NN	HSchW Discharge cbm/sec	HSchW Max. velocity m/sec	HHW El. over NN	Supplementary Information a. Riverbed and Channel b. Banks and Floodplain c. Remarks (Col. 17-19)
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
	Open River		80	3.6			77	1.1		188	1.45		640	2.4		
326.36	Mouth of Aller R.				6.45	7.45			8.93			11.93			13.43	
	Open River		100	3.5			134	0.9		297	1.15		930	2.4		b. Low banks. Flat, very wide, diked floodplain. High steep embankment, "Geestruecken," at BADEN (km 339-340), rising up to elevation 35.00m/NN. Important "ALTE ALLER" dead channel along the embankment between DAVERDEN and BADEN.
340.0	Upper Limit of Hemelingen Pool															
	Summer (3/16-11/14)				4.75	5.21			6.55			9.39			11.0	
	Winter (11/15-3/15)				5.6	6.06			7.4			10.36			12.03	
	Pool Condition		180-200	4			134			297			930	2.4		
362.0	Hemelingen Weir	8/47														
	Summer (3/16-11/14)				4.50	4.50			4.50							
	Winter (11/15-3/15)				5.50	5.50			5.50			5.15				

*General Map Reference

DESCRIPTION OF WATERCOURSE

Basin: Weser-Ems
River: Weser

All information refers to places (regions, watercourse stretches) in columns 1-2, arranged according to gradient, and their near surroundings, for purpose of representation of important, and for pertinent stretches characteristic, differences.

River km	Place, Watercourse stretch, resp.	Sheet No.* Obj. No.	Average Width m	Bed depth MThw / MTnW	MTnw El. over NN	MThw El. over NN	Discharge cbm/sec	Max. velocity m/sec	HThW El. over NN	Supplementary Information: a. Riverbed and Channel; b. Banks and Floodplain; c. Remarks (Col. 17-19) - NOTE: Col. 11-16 not applicable.
1	2	3	4	5	6	7	8	9	10	
362.0	Hemelingen Weir	8 / 47								
	Lower Weser		120	5.75 / 2.70	-1.92	-0.79 at 286 upstream disch.		0.60	2.95 at 286 upstream disch.	a. 60m navigation channel b. Bank protected by groins or riprap. Old riverbed of LITTLE WESER (KLEINE WESER) along left bank for approx. 1.2 km. c. Tide limit at HEMELINGEN WEIR. Riverbank area: gardens, meadows, recreation and sport areas, docks. Back area: urban developments.
366.8 (0.0)	Bridge (Bremen) (End of Upper & Middle Weser, start of Lower Weser kilometerage)		120	6.90 / 3.60	-1.92	-1.08	330	0.60	2.21	a. Heavy stone walls along most of riverbank. On left bank, 0.6 km below Bridge, BIG and LITTLE WESER R. separated by a small dike.
1.4	Railroad Bridge (Bremen)		140	7.40 / 4.10	-1.94	-1.10	360	0.60	2.20	a. 70 m navigation channel. b. Right Bank: Weser Railroad Station, industrial and harbor facilities. Left Bank: Starting at mouth of LITTLE WESER R., HOHENTOR HARBOR. Km 2.4; confluence of BIG and LITTLE WESER R. c. Head of navigation for ocean-going ships of 4-5 m draft. Riverbank area: industrial and sport areas. Back areas: urban developments.
4.0	Entrance to Free Harbor I		150	9.40 / 6.10	-1.99	-1.13	420	0.60	2.17	a. 70 m navigation channel. b. Right Bank: Harbor facilities. Left Bank: 500 m wide plain-meadows, pastures and fields. c. Ocean-going shipping to Free Harbor. Left bank area: bounded by WESER and OCHTUM dikes, includes NIEDERVIELAND marsh and villages of RABLINGHAUSEN and WESERDEICH.
5.5	Entrance to Free Harbor II		180	12.20 / 9.00	-2.01	-1.15	450	0.60	2.16	a. 100 m navigation channel. b. Right Bank: Shipyard Harbor, DESCHIMAG Shipyard, industrial and commercial harbor. Left Bank: Km 6-7.5 winter dike close to river; km 7.5, dike swings in a wide curve up to HASENBUEREN forming an 800 m wide floodplain. c. NIEDERVIELAND marsh landward of RABLINGHAUSEN and SEEHAUSEN, which are located along the left bank dike. Km 7.0, RABLINGHAUSEN Sluice, a 1.45 x 1.5m drainage outlet (2.17 sq m cross-sectional area) for NIEDERVIELAND marsh. A summer dike, crest elev. 3.20 m NN, begins at km 7.5, providing partial protection to the floodplain against WESER R. floods.

*General Map Reference

DESCRIPTION OF WATERCOURSE

Basin: Weser-Ems
River: Weser

All information refers to places (regions, watercourse stretches) in columns 1-2, arranged according to gradient, and their near surroundings, for purpose of representation of important, and for pertinent stretches characteristic, differences.

River km	Place, Watercourse stretch, resp.	Sheet No.* Obj. No.	Average Width m	Bed depth MThW / MTnW	NNW El. over NN	MTnW El. over NN	MTnW Discharge cbm/sec	MTnW Max. velocity m/sec	MThW El. over NN	Supplementary Information: a. Riverbed and Channel; b. Banks and Floodplain; c. Remarks (Col. 17-19) - Col. 11-16 not applicable
1	2	3	4	5	6	7	8	9	10	
8.5	Entrance to Industrial and Commercial Harbor		180	11.9 / 8.7	-2.06	-1.18	520	0.60	2.13	a. 120 m navigation channel b. Adjacent to Harbor Entrance is a lock leading to the industrial harbor area; lock length 170 m, 2 slide gates each 25 m wide. Right Bank: Km 8.5-10.6, slightly elevated floodplain Km 10.6-12.5, curving dike creates 500 m wide MITTELSBUEREN floodplain Km 12.5-14.0, dike close to river bank. Km 14.0-15.5, curving dike creates 160 m wide floodplain. Km 16.5, joining of WESER and LESUM R. valleys. Left Bank: Km 9.7 village of HASENBUEREN. Km 9.7-11, dike curves around HASENBUEREN, false channels. Km 12.5, dike, WESER and OCHTUM R. form a common valley, approx. 1 km wide. Km 14.2, Mouth of OCHTUM R. c. Right Bank: WERDERLAND marsh between WESER and LESUM R. Km 15.0, NIEDERBUEREN Sluices, each 1.0 m diam. ie. 0.75 qm cross-sectional area, total 75 qm area. (NOTE: "qm" equivalent to square meters) Left Bank: NIEDERVIELAND marsh between WESER and OCHTUM R. Km 9.0, 1.5 qm HASELBUEREN Sluice in dike. Floodplain below OCHTUM R., which together with OCHTUM KANAL were formerly the beds of the OCHTUM and WESER R., now defined by dike along west bank of OCHTUM KANAL. Km 15.1, Mouth of OCHTUM KANAL. Immediately downstream is the slightly elevated DEICHSHAUSEN Plain, now occupied by an airfield; WESER R. valley narrows to 300 m at this point.

*General Map Reference

DESCRIPTION OF WATERCOURSE-

Basin: Weser-Ems
River: Weser

All information refers to places (regions, water course stretches) in columns 1-2, arranged according to gradient, and their near surroundings, for purpose of representation of important, and for pertinent stretches characteristic, differences.

River km	Place Watercourse stretch, resp.	Sheet No.* Obj. No.	Average Width m	Bed depth MThW / MTnW	NNW El. over NN	[illegible] El. over NN	[illegible] Discharge cbm/sec	[illegible] Max. velocity m/sec	MThW El. over NN	Supplementary Information a. Riverbed and Channel b. Banks and Floodplain c. Remarks (Col. 17-19) - Col. 11-16 not applicable
1	2	3	4	5	6	7	8	9	10	
17.5	Mouth of Lesum R.		240	10.9 / 7.8	-2.00	-1.14	1400		2.0	a. 120 m navigation channel. b. Right Bank: High embankment, "Geest," with villages of VEGESACK, BLUMENTHAL, ROENNEBECK, and FARGE. Left Bank: Flat banks and floodplain, approx. 500 m wide, occupied by factories. Dikes along the WARFLETH and WESTERGATE old channels. Km 29, joining of the WESER and HUNTE R. valleys. c. Right Bank: Harbor of VEGESACK at the mouth of LESUM R. Km 28.6, BECKUM Sluice. Right back area: villages, forests, shifting surfaced wasteland; OSTERSTADE marsh beginning at Km 26. Left Bank: STEDINGEN marsh, a 2.5 km side depression extending westward to the OLLEN R., a tributary of the HUNTE R. Km 17.5, LEMWERDEN Sluice. Km 27.4, WESERDEICH Sluice.
32.6	Mouth of Hunte R.		340	10.4 / 7.1	-2.39	-1.48	2800		1.79	b. Right Bank: Km 33, right side channel of river in the middle of 2 km wide floodplain. Left Bank: Narrow floodplain, dikes close to stream. Villages along the dikes. Factories, shipyards and docks near the city of BRAKE. Harbor entrance 13.3 m wide. c. Right Bank: 3.5 km wide OSTERSTADE marsh in back area, extending to the "Geestrand." Km 34.0, Sluice, 2.75 m high x 2.87 m wide x 15 m long, bottom elev. -1.10 m/NN Km 36.6, ASCHWARDEN Sluice, 4.35 m high x 4.08 m wide, bottom elev. -1.86 m/NN Km 37.2, WURTHFLETH Sluice (Syphon type), 1.60 m diam., bottom of ditch -1.10 m/NN
			400					0.85		Left Bank: 7-10 km wide OLDENBURG-WESER Marsh, (a marshland and moorland region) in back area. Km 36.4 MOORLEHE Sluice, 2 openings, each 4.05 x 4.35 x 25 m, bottom elev. -2.70 m/NN Km 36.8, VAESEBURG Sluice, 4.20 x 4.85 x 22 m, bottom elev. -2.37 m/NN

[illegible] reference

DESCRIPTION OF WATERCOURSE

Basin: Weser-Ems
River: Weser

All information refers to places (regions, water course stretches) in columns 1-2, arranged according to gradient, and their near surroundings, for purpose of representation of important, and for pertinent stretches characteristic, differences.

River km	Place, Watercourse stretch, resp.	Sheet No.* Obj. No.	Average Width m	Bed depth MThW / MTnW	MNW El. over NN	MTnW El. over NN	MTnW Discharge cbm/sec	MTnW Max. velocity m/sec	MThW El. over NN	Supplementary Information a. Riverbed and Channel b. Banks and Floodplain c. Remarks (Col. 17-19) - Col. 11-16 not applicable
1	2	3	4	5	6	7	8	9	10	
40.6	Entrance to Brake Harbor		460	10.5 / 7.1	-2.55	-1.62	3700		1.80	b. Right Bank: 150 m wide floodplain up to mouth of right sidechannel at SANDSTEDT, Km 44.0. A dike close to the side channel up to DEDESDORF, Km 54.0. Km 54.0-56.3, outlet of depression formed by the OLD WESER R., which divides the LUNE PLATE from the main stream. Left Bank: A pier, approx. 1 km long, along the bank in the harbor region. Km 43.3, dike curves in wide arc up to 2 km away from the river, approaching the river again at Km 51.8. In that floodplain region is the STROHHAUSEN PLATE, separated from the back area by one old branch, "SCHWEIBURG." A dike runs in a flat arc along the other parts of the WESER R., forming a wide floodplain with the DEDESDORF PLATE. c. Right Bank: NORDER OSTERSTADE Marsh extending up to Km 51, LAND WUEHRDEN Marsh above that point. Both marshy regions 3-4 km wide. Km 42.0, 2 OFFENWARDEN Sluices, 2.0 (2.3) m high x 1.68 (2.37) m wide, bottom elev. -1.97 (-2.43) m/NN. Km 44.0, SANDSTEDT Sluice, 2.33 m wide, bottom elev. -2.28 m/NN. Km. 47.0, RECHTENFLETH Sluice, 2.20 m wide, bottom elev -2.32 m/NN. Km 49.0, DREPTE Sluice, 3.5 m wide, bottom elev. -2.29 m/NN. Km 50.3 NEUENLAND Sluice, with pump, 1.46 m wide, bottom elev. -1.97 m/NN. Km 50.9, BUTTELE Sluice, 2.5 m high x 1.80 m wide x 32 m long, bottom elev. -2.23 m/NN. Km 53.8, DEDESDORF Sluice, 4.0 x 4.0 x 27.5 m, bottom elev. -2.44 m/NN. Km 58.0, ERDMANN Sluice (LUNE PLATE), bottom -2.44 m/NN.
			630					0.96		Left Bank: Continuation of OLDENBURG-WESER Marsh. Approx. 1 km long pier above NORDHAM Harbor. Km 41.2, BRAKE Sluice. Km 44.5, GOLDZWARDEN Sluice. Km 45.6, SCHMALENFLETH Sluice, 2.70 m high x 3.52 m wide x 23.6 m long, bottom elev. -2.10 m/NN. Km 48.0, ABSEN Sluice (wood), 2.65 x 3.28 x 23.75 m, bottom elev. -1.57 m/NN. Km 49.0, STROHHAUSEN Sluice, 2 @ 2.90 x 2.10 x 10 x 20.75, bottom -2.14/NN. KM 51.6, BECKUM Sluice, 4.50 x 3.80 x 15.30 m, bottom -1.94 m/NN. Km 53.4, KLEINE Sluice, 2.80 x 2.0 x 2.0 x 19.0 m, bottom -1.57 m/NN. Km 56.0, GROSSE Sluice, 3.55 x 2.0 x 19.55 m, bottom -1.71m/NN.

*General map reference

DESCRIPTION OF WATERCOURSE

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River km	Place, Watercourse stretch, resp.	Sheet No.* Obj. No.	Average Width m	Bed depth MThW / MTnW	NNW El. over NN	MTnW El. over NN	MTnW Discharge cbm/sec	MTnW Max. velocity m/sec	MThW El. over NN	Supplementary Information a. Riverbed and Channel b. Banks and Floodplain c. Remarks (Col. 17-19) - Col. 11-16 not applicable
1	2	3	4	5	6	7	8	9	10	
58.7	Nordenham-Entrance to fishery harbor		800	-11.4 / 8.0	-2.75	-1.76	7200		1.71	a. Riverbank in original stream valley, 150 m navigation channel. b. Right Bank: Up to km 63.5 is the LUNE PLATE, a storm and flood-free, diked marshy island. East of it is a 1.6 km wide depression, "ALTE WESER," the north part of which is crossed by the LUNE R. which joins the WESER R. at km 63.5. A short distance above the mouth of the GEESTE R. (km 65.5) is the entrance to WESERMUENDE Fishery Harbor. The entrance is provided with a double lock of 100 and 105 m clear length, and 30 and 12 m clear width, respectively. Left Bank: Up to km 65.5; dike close to stream, floodplain approx. 200 m wide, industrial area of BLEXEN at top of bank. At km 65.5, the dike makes a right-angled turn to the Northwest to form a floodplain approx. 1 km wide. c. Right Bank: Marshy LAND WUEHRDEN depression and adjacent LUNE depression. At km 59.0, valley area contained by dikes approx. 3.2 km wide; at km 62.0, approx. 4.2 km wide; widening to 5 km at km 63.5; and narrowing to 2.5 km at km 64.5. LUNE LOCK, a concrete structure, clear width of 10 m and depth of 2.5 m at NW, 5.8 m at HW. Left Bank: BUTJADINGEN LAND, fairly completely populated. Km 59.1, FLAGBALGEN Sluice, 2.50 m high x 1.50 m wide x 19 m long, bottom -2.19 m/NN. Km 61.7, BLEXEN Sluice, 3.10 x 3.30 x 19 m, bottom -2.02 m/NN.
			1000					1.06		

*General map reference

DESCRIPTION OF WATERCOURSE

Basin: Weser-Ems
River: Weser

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River km	Place, Watercourse stretch resp.	Sheet No.* Obj. No.	Average width m	Bed depth MThW / MTnW	NNW El. over NN	MTnW El. over NN	MTnW Dis-charge cbm/sec	MTnW Max velo-city m/sec	MThW El. over NN	Supplementary Information a. Riverbed and Channel b. Banks and Floodplain c. Remarks (Col. 17-19) - Col. 11-16 not applicable
1	2	3	4	5	6	7	8	9	10	
66.3	Bremerhaven - limit between Lower and Outer Weser		1200	13.8 / 10.4	-2.92	-1.71	9800		1.67	a. Riverbed in original stream valley, 200 m navigation channel to mouth of the estuary. b. Widening of the stream mouth. Wide sand-flats, "Watten," along both sides of river, flooded at high tide but dry at low tide. Right Bank: FORT BRINKAMAHOF with lighthouse. Left Bank: LANGLUETJEN FORTS I and II, situated on low flat islands, "Watteninseln." c. Right Bank: City areas of BREMERHAVEN and WESERMUENDE located landward of their respective harbor areas. Km 66.7, NEUER HAFEN Lock, docking lock 22 m clear width, with high and low tide gate (miter gate type) Km 67.8, KLEINE KAISER Lock, docking lock 17 m clear width, high and low tide miter gates. Foreharbor and lock gates silted, depth at both locks 4.5 m at NW, 7.8 m at HW. Km 68.0, GROSSE KAISER Lock, chamber 223 m long x 28 m wide; high and low tide miter gate on riverward end, slide gate on landward end of lock.
	Outer Weser									a. Tidal effects persist as far upstream as the upper reaches of the LOWER WESER R. In the lower reaches of the LOWER WESER R. max. stream velocity is 1.0-1.7 m/sec. c. Km 69.3, NORD Lock, chamber 372 m long x 45 m wide, slide gates, depth 11.2 m at NW, 14.5 m at HW. Km 71.0, end of harbor area, adjacent LAND WURSTEN marshland. 3.5 km below entrance to NORD (North) Lock is WEDDEWARDEN Sluice; 10.0 km below that initial point, WREMEN Sluice; 17.5 km, PADDINGBUETTELER Sluice; 20.0 km, DORUM Sluice. Left Bank: North Sea marsh of BUTJADINGEN. 4.5 km below BLEXEN village, TETTENS Sluice; 7.0 m, WADDENS Sluice; 11.0 km, BURHAVE Sluice.
113.0	Rottersand Lighthouse-Beginning of sea area			13.2 / 10.5	-2.72	-1.60	1,000,000		1.12	

[illegible]

Location River km	Sheet No.* Obj. No.	Control Structure (Name & Purpose)	Pool Data a. Backwater Extent b. Pool Width c. Pool Depth d. Headwater Elev. e. Tailwater Elev.	Lock & Dam Data a. Lock b. Dam c. Bridgeway	Operation Effects a. Full Closure b. Full Opening c. Associated Results	Remarks
1	2	3	4	5	6	7
At HAMELN 134.8- 135.4 km	73 83	HAMELN WESER Weir Navigation Power	a. 5 km b. 112 m c. 3.7 (Max.) d. 63.79 m/NN e. 60.49 m/NN	a. #1. Concrete long-tow lock, chamber length 225 m, width-chamber & gate 12.5 m #2. Old ashlar masonry lock. Chamber length 61 m, width-chamber & gate 11 m b. 2 fixed weirs, concrete & ashlar masonry, lengths 135, 165 m c. Walkway 0.8 m	a - c. Fixed weir. Full opening and closing not possible.	
NW of DOERVERDEN 308.85 km	47 80a	DOERVERDEN Weir Navigation Irrigation Power	a. 22 km b. 130 m c. 5.8 m (max.) d. 14.60 m/NN e. 10.82 m/NN (MNW)	a. #1. Reinf. concrete long-tow lock; chamber length 350 m, width-chamber & gate 12.5 m c. #1. Walkway 0.8 m	a. Upstream: Headwater can be raised to 15.10 m/NN; creating 25 km backwater, partial flooding of banks near weir, increased power generation. Downstream: Resulting drop in stage causes navigation difficulty at MW & NW. b. Upstream: Lowering of headwater stage reduces navigable craft & disrupts power generation at normal stage & at NW. Downstream: Sudden opening endangers navigation and banks.	Power: 4 turbines, 2 generators. Peak capacity 2900 kw, average capacity 1950 kw, daily output 46,500 kwh. Emergency closure of weir openings by needles in event of failure of slide gates. "Attention at HW." Destruction: Shutdown of power plant would not materially affect weir operation; but current supply for weir operation would be interrupted by destruction of weir bridge.
	47 80b			a. #2. Small solid masonry lock, length 85 m, width-chamber & gate 12.5 m c. #2. Walkway 0.8 m		
	47 104a			a. #3. Solid concrete lock, length 28.2 m, width-chamber & gate 6.2 m c. #3. Walkway 0.54 m		
	47 104b			b. 3 double leaf slide gates (lower leaf 4 m, upper 3m, high) Additional 1 m high movable ice flap on upper leaf. Lengths 42, 42, 24m. c. #4. Walkway 3 m		

*General map reference

Weser Basin (Sequence Downstream) DESCRIPTION OF CONTROL STRUCTURES

Location River km	Sheet No.* Obj. No.	Control Structure (Name & Purpose)	Pool Data: a. Backwater Extent b. Pool Width c. Pool Depth d. Headwater Elev. e. Tailwater Elev.	Lock & Dam Data: a. Lock b. Dam c. Bridgeway	Operation Effects: a. Full Closure b. Full Opening c. Associated Results	Remarks
1	2	3	4	5	6	7
At Suburb of HASTEDT near BREMEN	47 / 8	HEMELINGEN WEIR (Bremen Weser Weir) Navigation, Irrigation, Power generation, Increase of river & ground-water levels	a. 11 km (summer) b. 150 m c. 4.5 m (max. at weir) d. 4.50 m/NN (summer) e. 5.50 m/NN (winter) e. 1.40 m/NN (mid-tide)	a. 2 concrete locks, clinker facing-chamber lengths 350 (70) Width-chamber & gate 12.5 m b. Concrete weir with stone facing, length 125 m. 2 sector gates, 54 m each c. Lock walkway 1.4 m, weir walkway 2 m	a. Upstream: Raising of head-water to between 6.20 to 7.0 m/NN creates: partial flooding of floodplain, flooding of LEESTE-BRINKUM Marsh on left bank & ARBERGER Marsh on right bank, & increase in OCHTUM River stage. (Cont'd. in Col. 7) b. Upstream: Stopping of navigation at low water, disruption of power generation	Power: 11 generators, total capacity 7750 kw; daily output 90,000 kwh in summer; 135,000 kwh in winter. Provides all electric supply for private & industrial usage in State of Bremen. Cont'd. from Col. 6: a. Retardation of cultivation of pastures & meadows, flooding of cellars in HEMELINGEN, interruption of navigation at stages above 6.20 m/NN Destruction: Disrupts vital food production, restricts important industrial production, impairs important coal, oil, lumber, grain transportation.

*General map reference

Eder Basin (Sequence downstream) Description of Control Structures

Location River km	Sheet No.* Obj. No.	Control Structure (Name & Purpose)	Pool Data a. Backwater Extent b. Pool Width c. Pool Depth d. Headwater Elev. e. Tailwater Elev.	Lock & Dam Data a. Lock b. Dam c. Bridgeway	Effects a. Full Closure b. Full Opening c. Associated Results	Remarks
1	2	3	4	5	6	7
1.5 km N. of HEMFURTH 2.5 km S. of WALDECK 44 km above mouth of Eder R.	96 34	Eder Dam (Edertalsperre) Flood protection Power Flow regulation	1/20 Full: (10 mil. cbm) a. 6 km d. 214.2 m/NN 1/2 Full: (101 mil. cbm) a. 17 km d. 233.9 m/NN Full: (202 mil. cbm) a. 26 km (max) c. 42 m (max. at dam) 26 m (at Brinkhausen) 15 m (at Asel) 5 m (at Herzhausen) d. 245.0 m/NN	b. Rubble stone masonry gravity dam. Crest 245.0 m/NN, foot 203.0 m/NN, emergency outlet 232.78 m/NN. c. Roadway along dam crest 2.5 m wide, elev. 247.0 m/NN. 2 walkways 1.0 m each	c. 230 cbm/sec discharge floods lower Eder & Fulda valley, damaging agriculture & disturbing traffic	Power: Powerhouse "I" on left bank, 6 turbines total cap. 9360 kw. Powerhouse "II" on right bank, 3 turbines, total cap. 18,480 kw. Discharge: Max. capacity of outlets (including turbines) 290 cbm/sec. Destruction: Discharge due to demolition would destroy villages and devastate Lower Eder & Fulda valley. Demolition of power installations create electric deficiency in Kassel Power A.G. Demolition bottom outlets would eliminate flood protection & water supply for Weser R.
On PETERSKOPF above HEMFURTH on right bank 41 km above mouth of Eder R.	96 185	Waldeck Reservoir. Pumping Storage, Power for Waldeck	Full: (0.76 mil. cbm) a. 320 m (mean) b. 155 m (mean) c. 20 m (max. at surge tank) d. 507.0 m/NN	b. Solid concrete structure Crest 507.6 m/NN, average elev. at foot 490.0 m/NN		Power: Powerhouse on right bank below Hemfurth, 4 turbines, (operated only during peak power demand periods) total cap. 115,200 kw Discharge: Max. cap. of outlet 48 cbm/sec. Destruction: Demolition of dam would destroy powerhouse, AFFOLDERN WEIR and village, and endanger villages in Eder Valley. Demolition of powerhouse by itself would create power deficit without damage to EDER DAM or AFFOLDERN RESERVOIR.
5.5 km below EDER DAM at AFFOLDERN 38 km above mouth of Eder R.	96 121	Affoldern Re-regulation Reservoir, Flood Protection, Power & Flow re-regulation (in connection with Eder Dam)	Minimum Pool: (1.63 mil cbm) d. 201.5 m/NN Full: (3.8 mil. cbm) a. 5.5 km c. 10 m (max.) d. 204.4 m/NN	b. Solid concrete gravity weir and adjacent earth dam. A 3.5 km long earth dam extension on left bank of Eder R. crest 205.5 m/NN	c. Sudden discharges damage agriculture, disturb traffic, & destroy villages in Lower Eder Valley	Power: 1 turbine, total capacity 2,560 kw, serviced by remote control from HEMFURTH power station. Discharge: Max. cap. of outlet 900 cbm/sec.. Destruction: Demolition of the structure would place pumping storage reservoir out of commission & impair water supply for Weser R.

*General map reference

Fulda Basin (Sequence Downstream)

DESCRIPTION OF CONTROL STRUCTURES

Location River km	Sheet No.* Obj. No.	Control Structure (Name & Purpose)	Pool Data: a. Backwater Extent b. Pool Width c. Pool Depth d. Headwater Elev. e. Tailwater Elev.	Lock & Dam Data: a. Lock b. Dam c. Bridgeway	Operation Effects: a. Full Closure b. Full Opening c. Associated Results	Remarks
1	2	3	4	5	6	7
At Rotenburg 12.35 km	97/49	Rotenburg Lock Navigation Bruising Mill Operation	a. 2.4 km b. 40 m (mean) c. 1.8 m (mean) d. 184.04 m/NN (normal) e. 182.20 m/NN (MNW)	a. Solid masonry lock, wood miter gates. Chamber length 27.3 m, width-chamber and gate 4.4 m b. Fixed weir with movable crest, length 60.4 m. Fixed crest 184.04 m/NN; movable crest 184.32 m/NN	a. None b. None c. No damage	Destruction: Navigation & mill operation suspended; downstream bridges and dams endangered.
At Neumorschen 26.55 km	97/146	Neumorschen Lock Navigation Flour Mill Operation	a. 2 km b. 35 m (mean) c. 1.6 m (mean) d. 175.16 m/NN (normal) e. 173.60 m/NN (MNW)	a. Solid masonry lock, wood gates. Chamber length 28.3 m, width-chamber 6 m, gate 4.5 m. b. Fixed weir with movable crest, length 77 m. Fixed crest 175.16 m/NN: movable crest 175.46 m/NN	a. None b. None c. No damage	Destruction: Navigation & vital mill operation suspended: downstream bridges and dams endangered.
At Melsungen 42.4 km	97/154	Melsungen Lock Navigation Power plant and mill operation	a. 1.7 km b. 60 m (mean) c. 1.5 m (mean) d. 164.68 m/NN (normal) e. 163.00 m/NN (MNW)	a. Solid masonry lock, wood miter gates. Chamber length 24.4 m; width-chamber 5.6 m, gate 4.4 m b. Fixed weir, length 191.0 m. Right bank crest 164.70 m/NN; left bank crest 164.66 m/NN	a - c. None	Destruction: Navigation & ~~unimportant~~ mill operation suspended; downstream bridges and dams endangered.
At Cuxhagen 61.15 km	97/163	Cuxhagen Lock Navigation Flour mill & dye mill operation	a. 1.6 km b. 65 m (mean) c. 1.7 m (mean) d. 147.24 m/NN (normal) e. 145.50 m/NN (MNW)	a. Solid masonry lock, wood miter gates. Chamber length 24.5 m; width chamber 4.6 m, gate 4.4 m b. Fixed weir, length 158 m Right bank crest 147.28 m/NN; left bank crest 147.24 m/NN	a - c. None	Destruction: Navigation & important mill operation suspended; downstream bridges and dams endangered.
Between Kassel and Bergshausen 75.5 km	85/92	NEUE MUEHLE Lock Navigation Operation of pumping and irrigation project	a. 3.7 km b. 90 m (mean) c. 2.3 m (mean) d. 138.72 m/NN (normal) e. 137.0 m/NN (MNW)	a. Solid masonry lock, wood miter gates. Chamber length 24.3 m; width chamber 5.85 m, gates 4.6 m b. Fixed weir, length 165 m Right bank crest 138.78 m/NN, left bank crest 138.73 m/NN	a. None b. Upstream mills and navigation out of commission. c. Sudden raising of roller gate weir creates a flood-wave downstream	Destruction: Closing down of pumping station causes suspension of water supply to a large part of Kassel. Navigation suspended. Bridges endangered.

*General Map Reference

Fulda Basin (Sequence Downstream)

DESCRIPTION OF CONTROL STRUCTURES

Location River km	Sheet No.* Obj. No.	Control Structure (Name & Purpose)	Pool Data: a. Backwater Extent b. Pool Width c. Pool Depth d. Headwater Elev. e. Tailwater Elev.	Lock & Dam Data: a. Lock b. Dam c. Bridgeway	Operation Effects: a. Full Closure b. Full Opening c. Associated Results	Remarks
1	2	3	4	5	6	7
At Kassel 81.3 km	85/95	Kassel Lock Navigation	a. 4.6 km b. 70 m (mean) c. 2.8 m (mean) d. 135.82 m/NN (normal) e. 133.02 m/NN (MNW)	a. Solid masonry lock, 3 iron miter gates. Chamber length 85 m, width-chamber 11.8 m, gate 10 m. b. 2 roller gates, length 24.3 m each. Crest 135.82 m/NN. c. Walkway over lock 1 m, over weir 1.4 m	a. None b. Upstream flour mill & navigation disrupted. c. Flood wave created by sudden roller gate opening	Destruction: Navigation & important mill operation suspended; downstream bridges and dams endangered.
W. of Wolfsanger 85.5 km	85/98	Wolfsanger Lock Navigation	a. 4.2 km b. 55-60 m c. 1.8 m (max.) d. 132.98 m/NN e. 131.34 m/NN (MW)	a. Solid masonry lock, wood miter gates. Chamber length 60 m, width-chamber & gate 8.6 m b. 1 fixed & 2 needle weirs, lengths 24.4, 30.2, 26.6 m. c. Walkway for weir servicing.	a. Insignificant b. Upstream navigation stopped c. Flood wave of short duration created by sudden opening	
N. of Spiekershausen 89.5 km	85/100	Spiekershausen Lock Navigation	a. 4 km b. 55-60 m c. 1.8-2 m (max.) d. 130.98 m/NN e. 129.33 m/NN (MW)	a. Solid masonry lock, wood miter gates. Chamber length 60 m, width-chamber & gate 8.6 m b. 2 fixed & 2 needle weirs, lengths 30.3, 26.6, 26.1, & 15 m c. Walkway for weir servicing.	a - c. Same as above.	
Near Kragenhof 92.9 km	85/102	Kragenhof Lock Navigation	a. 3.4 km b. 55-60 m c. 1.8-2 m (max.) d. 129.98 m/NN e. 127.37 m/NN (MW)	a. Same as Spiekershausen b. 2 needle weirs, lengths 30.3 & 26.6 m c. Walkway for weir servicing	a - b. Same as above c. Spiekershausen Ferry out of commission	
S. of Speele 97.0 km	85/104	Speele Lock Navigation	a. 4.1 km b. 55-60 m c. 1.8-2 m (Max.) d. 127.18 m/NN e. 124.92 m/NN (MW)	a. Same as Spiekershausen b. 1 fixed & 1 needle weir, lengths 46 & 17.5 m. c. Walkway for weir servicing	a - c. Same as	

*General map reference

Fulda Basin (Sequence Downstream)

DESCRIPTION OF CONTROL STRUCTURES

Location River km	Sheet No.* Obj. No.	Control Structure (Name & Purpose)	Pool Data: a. Backwater Extent b. Pool Width c. Pool Depth d. Headwater Elev. e. Tailwater Elev.	Lock & Dam Data: a. Lock b. Dam c. Bridgeway	Operation Effects: a. Full Closure b. Full Opening c. Associated Results	Remarks
1	2	3	4	5	6	7
S. of WILHELM-SHAUSEN 101.5 km	85/106	Wilhelmshausen Lock Navigation	a. 4.5 km b. 55-60 m c. 1.8-2 m (max.) d. 124.52 m/NN e. 122.46 m/NN (MW)	a. Same as Spiekershausen b. 2 needle weirs, lengths 30.3 & 26.6 m c. Walkway for weir servicing	a.- b. Same as above c. Wilhelmshausen Ferry above dam out of commission	
N. of BONAFORT 105.3 km	85/233	Bonafort Lock Navigation	a. 3.8 km b. 55-60 m c. 1.8-2 m (max.) d. 122.06 m/NN e. 120.11 m/NN (MW)	a. Same as Spiekershausen b. 2 needle weirs, lengths 30.3, 26.6 m c. Walkway for weir servicing	a - c. Same as above	a - c. None
At Tanzwerder in Hann Muenden 108.3	85/234	HANN MUENDEN Lock Navigation	a. 3 km b. 55-60 m c. 2.2-2.4 m (max.) d. 119.65 m/NN e. 117.10 m/NN (MW)	a. Solid masonry lock, iron miter gates. Chamber length 60 m; width-chamber & gate 8.6 m b. 2 fixed weirs, lengths 200, 51 m c. Roadway 1.65 m, 2 walkways 0.6 m; single load capacity 2.5 tons		

*General map reference

Diemel Basin (Sequence Downstream)

DESCRIPTION OF CONTROL STRUCTURES

Location River km	Sheet No.* Obj. No.	Control Structure (Name & Purpose)	Pool Data: a. Backwater Extent b. Pool Width c. Pool Depth d. Headwater Elev. e. Tailwater Elev.	Lock & Dam Data: a. Lock b. Dam c. Bridgeway	Operation Effects: a. Full Closure b. Full Opening c. Associated Results	Remarks
1	2	3	4	5	6	7
Above HELMINGHAUSEN	84 / 169	DIEMEL DAM (Diemel Talsperre) Flood Protection Power Flow regulation	1/7 Full (3 mil. cbm) a. 2.5 km d. 359.4 m/NN 1/2 Full (10 mil. cbm) a. 4.5 km d. 368.7 m/NN Full (20.05 mil. cbm) a. 6.5 km c. 42 m (Max. at dam) 13 m (at STORMBRUCH Bridge) d. 376.2 m/NN	b. Ashlar Masonry gravity dam. Crest 376.2 m/NN Foot 340.0 m/NN c. Bridge roadway 5 m, elev. 378.2 m/NN. 2 walkway 0.88 m each	c. 60 cbm/sec discharge creates major flood in lower Diemel Valley, with disturbance of agriculture & traffic	Discharge: Max. capacity of discharge gates 34 cbm/sec Power: 2 turbines, total capacity 1060 kw. Reserve power supply available from KASSEL Power A.G. in emergencies. Destruction: Destruction of villages & devastation of valley below dam. Dam inoperative if bottom outlets destroyed.
350 m below Diemel Dam	84 / 206	HELMINGHAUSEN Re-regulation Reservoir, Flood protection, Flow re-regulation in connection with Diemel Dam	Full (65,000 cbm) a. 0.35 km c. 4 m (max. at dam) d. 341.5 m/NN	b. Solid concrete weir with slide gate outlets. Crest 342.5 m/NN, feet 336.90 m/NN c. Reinforced concrete roadway 3.5 m, walkway 1.0 m. El. 343.50 / NN. Short earth dam on both ends of the bridge	c. Agricultural damages & traffic disturbances can be reduced by gradual discharge	Discharge: Max. capacity of discharge gates 114 cbm/sec Refilling: 2 hrs. to refill at 10 cbm/sec discharge from DIEMEL DAM.

*General map reference

WESER RIVER SYSTEM

GEOGRAPHIC NAMES & LOCATIONS

Place Name	Sheet No.* GSGS 4416 1:100,000	GSGS 4414 1:25,000	"Nord de Guerre" Grid Reference
Absen	L 3	2616	4834
Affoldern	R 3	4820	9486
Ahauhausen	M 3	3019	8089
Ahsen	M 3	3020	9086
Albungen	R 4		5793
Allendorf	Q 4		5699
Aller River Mouth	M 3	3021	9784
Altenbrunslar	R 4	4822	1986
Altenbuecken	M 3	3220	9565
Altenburg	R 4	4822	1781
Alt Muenden	Q 4	4523	3216
Anraff	R 3	4820	9984
Arbergen	M 3	2919	7894
Arsten	M 3	2919	7593
Aschwarden	L 3	2717	5321
Aulhausen	N 3	3719	8107
Babbenhausen	P 3	3719	7601
Baden	M 3	3020	9089
Bad Lauterberg	Q 5		9040
Bad-Oeynhausen	P 3	3718	7301
Bad Sooden	Q 4		5699
Balge	N 3	3221	9859
Barkhausen	N 3	3719	8107
Barme	M 3	3121	9871
Battenfeld	R 3		6469
Beckum (Reckum)	M 3	2717	5214
Beckum Sluice	L 3	2516	4937
Bergshausen	Q 4	4722	2397
Bergheim	R 3	4820	9786
Beverungen	Q 4	4322	1342
Bierdem	M 3	2920	8591
Binnen	N 3	3320	9448
Blexen	L 3	2417	5349
Blumenthal	M 3	2817	5509
Bodenwerder	P 4	4023	2276
Bollen	M 3	2919	8190
Bonafort	Q 4	4523	3113
Bornhorst	M 2		3208
Braake	M 3	2817	6004
Brake	L 3	2616	5026
Bremen	M 3	2918	7099
Bremen-Neuenlande	M 3	2918	7295

*GSGS Map Series, Germany; Geographic Section of the General Staff, British War Office, 1944; (available from Army Map Service, Corps of Engineers, U. S. Army).

Place Name	Sheet No.* GSGS 4416 1:100,000	GSGS 4414 1:25,000	"Nord de Guerre" Grid Reference
Bremerhaven	L 3	2417	5550
Brevoerde	P 4	4022	1669
Brinkum	M 3	2918	7192
Bruchhausen-Vilsen	M 3	3120	8672
Buchholz	N 3	3520	8729
Buchhorst	N 3	3321	9856
Buehren	N 3	3320	9549
Buettel	L 3	2511	5337
Burhave Sluice	L 3	2416	4353
Bursfelde	Q 4	4423	3028
Butjadingen Land	L 3	2416	4549
Cuxhagen (Guxhagen)	R 4	4722	2191
Cuxhaven	K 3		6487
Dalheim	Q 3	4521	0121
Daverden	M 3	3020	9586
Dedesdorf	L 3	2517	5139
Dedesdorf Plate	L 3	2516	5040
Deichshausen	M 3	2817	5905
Dennhausen	Q 4	4722	2296
Diemel R., Mouth	Q 4	4322	1839
Diemeltalsperre (Diemel Dam)	Q 3		6909
Deisel	Q 4	4422	1734
Dittershausen	Q 4	4722	2196
Doerverden Weir	M 3	3121	9974
Drakenburg	N 3	3321	9955
Dreye	M 3	2919	7792
Eberschuetz	Q 4	4422	1228
Edertalsperre (Eder Dam)	R 3	4820	9288
Eder River Mouth	R 4	4722	2092
Eidewarden	L 3	2517	5140
Eisbergen	P 3	3820	8801
Eissel	M 3	3021	9885
Elsfleth	M 3	2716	4917
Emmern	P 4	3922	1385
Erder	P 3	3819	8299
Eschwege	R 4		6290
Estorf	N 3	3420	9544
Falken	R 4		7782
Farge	M 3	2717	5312
Fischbeck	P 3	3821	0795
Flagenbalgen Sluice	L 3	2516	5045
Frankenberg	R 3	4918	7474

Place Name	Sheet No.* GSGS 4416 1:100,000	GSGS 4414 1:25,000	"Nord de Guerre" Grid Reference
Fritzlar	R 3	4821	0782
Fuerstenberg	Q 4	4222	1549
Fuhlen	P 3	3821	0396
Fulda R., Mouth	Q 4	4523	3315
Geestemuende	L 3	2417	5649
Geeste R., Mouth	L 3	2417	5649
Gensungen (Gesungen)	R 4	4822	1882
Germete	Q 3	4520	9522
Giershagen	Q 3		7414
Gieselwerder	Q 4	4323	2535
Gimte	Q 4	4523	3217
Golzwarden	L 3	2616	4828
Grave	P 4	4023	1969
Grifte	R 4	4722	2091
Grinden	M 3	3020	9087
Grohnde	P 4	3922	1681
Grossenwieden	P 3	3821	9998
Grosse Kaiser Lock	L 3	2417	5452
Grosse Sluice	L 3	2516	4942
Guntershausen	R 4	4722	2194
Guxhagen	R 4	4722	2291
Habenhausen	M 3	2919	7595
Haevern	N 3	3519	8626
Hagen Grinden	M 3	3020	9288
Hagenohsen	P 4	3922	1485
Hajen	P 4	3922	1679
Hameln	P 4	3822	1090
Hann Muenden	Q 4	4523	3315
Hasbergen	M 3	2917	6298
Hasenbueren	M 3	2818	6403
Hastedt	M 3	2919	7597
Havern	N 3	3520	8626
Haueda	Q 3	4521	0321
Hedemuenden	Q 4		4111
Hehlen	P 4	4022	1978
Helmarshausen	Q 4	4322	1938
Helminghausen	Q 3		6909
Hemelingen Weir	M 3	2919	7596
Hemfurth	R 3	4072	9286
Hersfeld Fulda Weir	R 4		3853
Herstelle	Q 4	4322	1639
Hespringenhausen	Q 3		7920
Hessisch-Oldendorf	P 3	3821	0398
Hilwartshausen	Q 4	4523	3218
Hoexter	P 4	4222	1354
Hohenrode	P 3	3820	9798

Place Name	Sheet No.* GSGS 4416 1:100,000	GSGS 4414 1:25,000	"Nord de Guerre" Grid Reference
Holtorf	N 3	3020	8886
Holtrup	P 3	3719	7601
Holtrup	M 3	3220	9663
Holzbalge	N 3	3221	9758
Holzminden	P 4	4122	1760
Horstedt	M 3	2919	8490
Hoya	M 3	3120	9568
Hunte R., Mouth	M 3	2716	4917
Hutbergen	M 3	3021	9782
Ilysee	N 3	3520	8730
Intschede	M 3	3020	9386
Joessen	N 3	3619	8623
Kaeseburg (Kueseburg)	L 3	2716	5022
Karlshafen	Q 4	4322	1840
Kassel	Q 4	4623	2303
Kemnade	P 4	4023	2277
Kirkchohsen	P 4	3922	1484
Kleine Kaiser Lock	L 3	2417	5451
Kleine Sluice	L 3	2516	4939
Kohlenstaedt	P 3	3820	9700
Kragenhof	Q 4	4623	2509
Lachem	P 3	3821	0595
Lahde	N 3	3619	8520
Lamerden	Q 3	4421	1026
Landesbergen	N 3	3420	9340
Langwedel	M 3	3021	9888
Land Wuehrden	L 3	2517	5340
Lankenau	M 3	2818	6701
Latferde	P 4	3922	1683
Laubach	Q 4		3714
Leese	N 3	3420	9435
Leeseringen	N 3	3320	9546
Leeste	M 3		7288
Leine R., Mouth	N 4		2660
Lemwerder	M 3	2817	5907
Lesum R., Mouth	M 3	2817	5908
Letzter Heller Dam	Q 4		3714
Liebenau	Q 3	4521	0723
Liebenau (in Hannover)	N 3	3320	9346
Lienen	L 3	2716	4918
Lippoldsberg	Q 4	4323	2537
Lohne	P 3		6400
Lohre	R 4	4822	1580
Luechtringen	P 4	4222	1656
Lune Lock	L 3	2417	5547
Lune Plate	L 3	2517	5244
Lutter	S 4		4310

Place Name	Sheet No.* GSGS 4416 1:100,000	GSGS 4414 1:25,000	"Nord de Guerre" Grid Reference
Mahndorf	M 3	2919	8194
Mandern	R 3	4821	0282
Marsberg	Q 3	4519	7718
Mehlbergen	N 3	3320	9655
Mehlen	R 3	4820	9586
Mehringen	M 3	3120	9571
Meinbrexen	Q 4	4322	1545
Melsungen	R 4		2683
Minden	N 3	3719	8111
Mittelsbueren	M 3	2818	6204
Moorleme Sluice	L 3	2716	5022
Muehlgraben	R 4		7782
Muesleringen	N 3	3520	8833
Neelhof	P 3	3820	9499
Neesen	N 3	3719	8107
Neuemuhle	Q 4	4722	2299
Neuenkirchen	M 3	2717	5216
Neuenlande	L 3	2517	5336
Neuer Hafen Lock	L 3	2417	5550
Neuhof	N 3	3520	9231
Neumorschen	R 4		3175
Niedervieland Marsh	M 3	2818	6400
Niedermarsberg	Q 3	4519	7819
Niedermoellrich	R 4	4822	1480
Nienburg	N 3	3321	9950
Nordenham	L 3	2516	4943
Norder Osterstade Marsh	L 3	2617	5330
Nord Lock	L 3	2417	5453
Northeim	Q 4		5648
Obersmarsberg	Q 3	4519	7717
Obermoellrich	R 3	4821	1081
Obervieland	M 3	2918	7295
Oberwegwurth	S 4		3040
Ochtum R., Mouth	M 3	2817	6005
Oder R., Mouth	Q 4		6344
Oder Valley Dam (Odertalsperre)	Q 5		9142
Oedelsheim	Q 4	4423	2833
Offenwarden	L 3	2617	5327
Ohr	P 4	3922	1186
Ohsen-Tuendern	P 4	3922	1286
Oldenburg	M 2	2815	3005
Oldenburg-Weser-Marsh	L 3	2716	5215
Ossendorf	Q 3	4420	9324
Osterode	Q 4		7450
Osterstade Marsh	L 3	2617	5428
Ovenstadt	N 3	3519	8425

Place Name	Sheet No.* GSGS 4416 1:100,000	GSGS 4414 1:25,000	"Nord de Guerre" Grid Reference
Padberg	Q 3		7211
Padingbuettaler	L 3	2316	5067
Pegestorf	P 4	4022	2171
Petershagen	N 3	3619	8420
Peterskopf	R 3	4820	9085
Polle	P 4	4122	1567
Porta	P 3	3719	8106
Raune-Bingartes Mill	R 4		3853
Rechtenfleth	L 3	2617	5132
Rehme	P 3	3719	7602
Rhume R., Mouth	Q 4		5350
Rieda	M 3	3121	9877
Rimbeck	Q 3	4420	9125
Rinteln	P 3	3820	9200
Roennebeck	M 3	2817	5410
Rohrsen	N 3	3221	0158
Rotenburg	R 4		3968
Roter Sand Lighthouse	L 2		3369
Ruehle	P 4	4023	2271
Rumbeck	P 3	3821	0096
Salzuflen	P 3		6787
Sandstedt	L 3	2617	5230
Schaeferhof	N 3	3321	9847
Schluesselburg	N 3	3520	9132
Schmalenfleth	L 3	2616	4830
Schwalm River Mouth	R 4	4822	1781
Schweringen	N 3	3221	9862
Sebbenhausen	N 3	3221	9860
Seehausen	M 3	2818	6502
Sielen	Q 4	4422	1429
Soesse R., Mouth	Q 4		5948
Soesse Valley Dam (Soesseltalsperre)	Q 4		7852
Speele	Q 4	4623	2710
Spichra	R 4		7571
Spiekershausen	Q 4	4623	2707
Stapelshorn	M 3	3120	8871
Stedingen Marsh	M 3	2817	5708
Stedorf	M 3	3121	9974
Steinmuhle	P 4	4023	1371
Stolzenau	N 3	3420	9135
Streek	M 3	3020	9088
Strohausen Plate	L 3	2616	5032
Sudderade	M 3	2717	1721

Place Name	Sheet No.* GSGS 4416 1:100,000	GSGS 4414 1:25,000	"Nord de Guerre" Grid Reference
Tettens Sluice	L 3	2416	5050
Thedinghausen	M 3	3020	8686
Treffurt	R 4		7484
Trendelburg	Q 4	4422	1732
Twiste R., Mouth	Q 3	4520	9721
Uessen	M 3	3020	8890
Veckerhagen	Q 4	4523	2923
Vegesack	M 3	2817	5908
Veltheim	P 3	3819	8499
Verden	M 3	3021	0082
Vlotho	P 3	3819	7797
Volkmarshausen	Q 4	4523	3518
Vorbruch	M 3	2717	2817
Waddens Sluice	L 3	2416	4752
Wahmbeck	Q 4	4323	2337
Waldecker Talsperre	R 3	4820	9288
Warburg	Q 3	4520	9922
Warfleth	M 3	2817	5310
Weddewarden Sluice	L 3	2417	5356
Wega	R 3	4821	0182
Wehrbergen	P 3	3821	0893
Wehrden	Q 4	4222	1447
Werderland Marsh	M 3	2817	6105
Wernshausen	S 5		8439
Werra R., Mouth	Q 4	4523	3315
Werre R., Mouth	P 3	3718	7403
Weserdeich	M 3	2716	4815
Wesermuende	L 3	2417	5652
Weser R., Source	Q 4	4523	3315
Westergate Channel	M 3	2716	5018
Wilhelmshausen	Q 4	4525	2813
Windheim	N 3	3520	8625
Winkel	M 3	3020	9686
Wolfershausen	R 4	4822	1988
Wolfsanger	Q 4	4623	2705
Wrexen	Q 3	4419	8724
Wulmstorf	M 3	3020	9386
Wulsdorf	L 3	2417	5746
Wurthfleth	L 3	2717	5322

APPENDIX B

GEOLOGY OF WESER*

*Abstracted from "Report on Weser River (less Aller River) Part 1," prepared by G.S.I. (R.E.) Hq 21 Army Group, March 1945.

Geology of WESER River

This Appendix is based on material supplied by I.S.T.D.

The description of the river course is divided into sections by sheets of G.S.G.S. 4416.

Attention is directed to the nature of the river banks, river plains and neighbouring hills as a source of constructional material.

Liability to flooding and nature of vegetation are not dealt with specifically.

A. SHEET Q.4.

The river valley averages ½ mile in width widening in places to a mile, narrowing in gorges to ¼ mile or less. On either side, sandstone hills with steep slopes rise to 984 - 1312 ft. above sea-level. The lower hill slopes are loess* covered. The river plain is loam, sandy and gravelly in parts, with well-marked terraces.

Hann Münden.

Hann Münden 3415 lies on a small loess and loam covered plain where the rivers Werra and Fulda meet, surrounded on all sides by sandstone hills. To the West of the town, Stauffenkuppel hill is built of a basalt plug 3/4 mile wide. Further to the North-West Gahrenberg 2817 is another larger basalt mass. The river banks and plain in this area are of loam.

Volkmarshausen. 3518.

The river plain is mainly of gravel and sand. The sandstone hills are covered in their lower parts by loess to South and West of the town; there is a small marsh South-West of the town.

Veckerhagen. 30241

River banks of loam. River plain of loam and loess with terraces of gravel and river sand. At foot of hills are alluvial cones of sand and gravel, on one side of which the town Veckerhagen is situated. Hills of sandstone.

Veckerhagen - Oedelsheim. 2934.

Narrow river valley flanked by sandstone hills. River plain of loam and loess chiefly as terraces. South-East of Gottsbüren 2233, and West of Hemeln 3024 there are hills of basalt.

Oedelsheim - Helmarshausen. 1940.

Sandstone hills on each side of river, lower slopes loess covered especially around Bodenfelde 2640. River plain mainly loam except around

*Loess is a fine sandy loam deposited by wind. It is usually well-drained but when wet, it is very sticky.

Wahnbeck 2438 and Lippoldsberg 2638, where sandy gravel banks are developed.

Helmarshausen - Wehrden. 1447.

Hills to East are still sandstone but to West of valley the rocks are limestone and shales. River plain widens and gravel banks become more numerous chiefly along the right bank. There are patches of loess on the lower hill slopes.

Wehrden - edge of sheet.

Hills to West are capped by hard limestone. To East of river, sandstone hills with steep slopes. River plain loess and loam terraces with gravel banks along river and also along foot of hills East of river.

B. SHEET P4.

Average width of river valley 3/4 mile, narrowing to $\frac{1}{2}$ mile, widening to $1\frac{1}{2}$ miles in places. On both sides of river, hills rise to 820 - 984 ft. Along East side of valley sandstone occurs as far North as Bodenwerder 2377, except for some limestone/shale hills between Lobach 2365 and Pegestorf 2071. North of Bodenwerder hills to East of river are of limestone/shale series. Along West side of river valley, the hills are of limestone/shales with a capping of hard limestone. North of Bodenwerder, West of valley, and also South of Hameln 1291, younger rocks of shales, sandstones and dolomites with gypsum and coal beds occur locally. Along the river valley loess covers the lower hill slopes and parts of the valley floors. Terraces of sand and loam become increasingly important Northwards from Grohnde 1682 especially around Hameln. South of Grohnde sand banks and terraces are well-marked on the inner parts of the river-bends.

Hoxter 1455 - Holzminden 1860.

River alluvium mainly sand. Three terraces rise towards hills; that are composed of loam and loess underlain in parts by sand and gravel. Along the river course, pockets of sand and gravel occur. Loess covers large areas West and East of Holzminden.

Holzminden - Polle 1598.

Gentle sloped hills each side of river composed of thin bedded limestones and shales with the hilltops composed of hard limestone. River alluvium mainly sand with some gravel and loam patches, flanked by loess and gravel terraces. North-South belt of old river clay East of river near Bevern 2164 which is, itself, on a gravel bank.

Polle - Hajen 1780.

From Pegestorf 2072 to Bodenwerder 2377 hills East of the valley are of sandstone. Elsewhere in this section the hills are of thin limestones and shales, most of the hills having a capping of hard limestone. On the

lower hillslopes, rocks are chiefly clays with an extensive cover of loess. One mile South-East of Helken 1978 there is a gravel hill. Along the river valley, the banks are of loam with a narrow band of river loam on each side. Then come terraces of loess and gravel. Between Pegestorf and Bodenwerder, the sandstone hills East of the river have, at the foot of their slopes, accumulations of rock boulders and pebbles (screes).

Hajen - Kirchoksen. 1484.

Right bank of river sandy to gravelly backed by low terraces of loam (which is sandy in parts) and clay. At Hagenoksen 1585 a limestone cliff overlooks the river bank. The left bank of the river is mainly loam with a few gravel patches, West of which there is an extensive belt of terraced loam and loess which also covers the lower hill slopes practically everywhere. Forst Grohnde hill to West is built of sandstone; elsewhere the hills are chiefly shales with limestone bands in places.

Hameln. 1291.

Narrow belt of sand and gravel along river flanked on each side by loam plain up to 1,000 yards wide (on which town is built). Forst hill to North-East is of limestone, hard in parts. Lower hills to south-west of town are of dolomite marls with hard limestone bands. Lower hillslopes covered by loess. Just north-east of Hameln some small hills are capped by gravel terraces.

C. SHEET P.3.

Within the large river loop between Rinteln and Porta 8005 there are extensive loess and gravel terraces which continue eastwards along the North bank of the river to Hess Oldendorf 0398. The east-west ridge running along the North of the river is built of oolitic limestone in its upper part, underlain by shales, ironstones and sandstone beds which form the southern slopes overlooking the Weser Valley. South of the river the hills are composed of sandstone and limestone with shales in the valleys; the lower hill slopes are covered for the most part by loess.

The river plain in this sheet is covered mainly by 6.6 - 13.1 ft. of river clay loam overlying 13.1 - 23.0 ft. of sand and gravel. The sand and gravel comes to the surface on terraces along the valley sides.

Wehrbergen 0893 - Grosswieden 0098.

The river plain is composed of loam with many winding depressions of river clay. The river banks are predominently sandy to gravelly. The hills to the south-west are of dolomitic marls capped by hard sandstones and quartzites. To north-west of the river the hills are of limestone overlying clays which outcrop in the valleys. Lower hill-slopes, throughout this section, are extensively covered by loess.

Grosswieden - Eisbergen 8801.

River banks of gravel and sand. River plains of loam with a little gravel near Rinteln. Ridge to north of massive limestone (sandy in parts,

with iron ore beds) underlain by clays which form the lower hill slopes, chiefly loess covered, facing the Weser valley. Gravel accumulations are widespread along the foot of the ridge. North of Eisbergen, and just south of Steinbergen 9502 there are local clay areas. South of the river the hills are of sandstone, underlain by clays in the valleys. From Krankenhaven 9296 to Stemmen 8798 there is a belt of glacial gravel; loess covers many of the lower hill slopes and smaller valley sides.

Eisbergen-Babbenhausen 7601

The river cuts a gorge through sandstone rock. The river banks are of sand, flanked by a narrow belt of river loam. Hills to north of Uffeln 7898 of sandstone. North of Vellheim 8400 there is a large patch of glacial clay sand and gravel. Hills to the south of the river are of various rock types; a sandstone ridge runs approximately west-north-west-east-southeast south of Varenholz 8598. Further south there are limestone hills south of Kalldorf 8196 and more sandstone hills. The intervening valley tracts are cut in clay rocks with much surface glacial clay. Loess is confined to small patches in the valley sides.

Babbenhausen-Porta

Between the sand-stone gorge at Vlotho and the limestone gorge at Porta, the river forms a local plain. Here the river banks and plains are of loam with patches of fine sand and gravel. East of the river and railway, there is an extensive terrace of loess and gravel. West of the river, the ground rises to form low hills of limestone and clay rocks, with a small belt of loam and loess on the river side.

D. SHEET N.3.

The Weser river enters the North German plain at Minden 8111. The river plain does not show any sudden change. Away from the river however, the hills have given place abruptly to low undulating tracts and terraces of soft rocks (loess, loam, sand and gravel) in the depressions of which are wide stretches of swampy ground and marsh. The river plain is characterized as above Minden, by a narrow belt of river alluvium, mainly clay loam, with marginal terraces of sandy to gravelly composition which are more extensive and continuous than in the hill country further south. Downstream, the belt of river alluvium gradually widens to approximately 2 miles at Nienburg, the river course winding from side to side.

Minden area.

River banks of fine sand and loam. South of the town there is a small river plain of loam. The town itself is located on a loess terrace. East and west of the river plain, there is a belt of loam terrace, underlain by sand gravel. Westwards from Rodenbeck 7810 the terrain becomes marshy and the soil clayey. Eastwards from Meissen-Dankersen 8408-8412 the sub-surface is clay covered in places by loess which is often coarse grained. South of Minden the lower slopes of the Weser Gebirge are loess covered with patches of marly soil.

Petershagen Area 8422.

From Minden to Petershagen, the river is confined, rather closely, between high terraces on the west, of clay rocks, and lower terraces on the east of fine sandy loam and gravel. The river banks are of clay loam.

Petershagen-Nienburg.

Detailed information is absent. Along the left bank to Stolzenau 9136 dry elevated terraces are close to the river course for the most part. Along the right bank large stretches of river alluvium, mainly clay loam, are predominant, interrupted in places by terrace spurs. North of Stolzenau the river is flanked on both banks by river alluvium and low ground of clay loam. The terraces set back a mile or so from the river are most extensive to the West; to the east they are narrow and are replaced eastwards by marsh and swamp. North of Nienburg, the right bank of the river becomes more favourable due to the presence of loess sand and loam, but details of its extent and nature are not available.

E. SHEET M.3.

Detailed information is only available for the northern part of the river course, in the Bremen area. The part above Verden is known imperfectly. Here the river alluvium chiefly clay loam, forms a broad belt 2 miles wide which becomes more and more marshy down river. Along the left bank, the high terrace margin swings away from the river near Hoya 9569 so that the river alluvium is flanked by lower ground, normally dry, but liable to flooding or water-logging. Along the right bank, conditions are more favourable due to the presence of a low sand-dune belt (probably sandy loam) interrupted south of Verden by the marshy flood plain of the Aller river.

Below Verden there is a rapid deterioration in the nature of the river banks and plain. The river alluvium is mainly a clay belt broadening to 5 miles below Bremen, (the vertical thickness of which increases downstream) underlain by sand and gravel. The river banks may be occasionally sandy, but their foundations will always be clayey and soft with low bearing strength. Along the north bank, sand-dunes (chiefly fine sandy loam) form higher drier ground along a narrow belt on which Bremen, and Achim are located. Along the left bank, however, the marsh clay extends for some distance (5 miles) from the river before drier sandy ground occurs. The terraces, if present, lie more than 10 miles south-west of the river. Everywhere in this district swampy tracts are frequent, but peat does not appear to be prevalent.

Horsted-Hemlingen 8490-7596

This part has a surface cover of heavy soft marsh clay down to a depth of about 9.8 ft. below which firmer sand gravel and clay has been proved to 164 ft. and more below surface. The river banks are clayey except along the inner banks of the river bends, more especially the east bank north of Dreye 7792 where sand occurs. Habenhausen 7594 is on a sandy area. The marsh clay extends south-westwards to Brinkum 7191 and Kirchweye

7689 where fairly dry sandy ground begins. North of the river the marsh clay gives place to fine waterlogged sand south of Uphusen 8392. Then comes the Achim 8892 - Uphusen - Hastedt 7797 belt of dry sand and sandy loam which extends north-westwards under Bremen.

Bremen.

The North river bank consists of a narrow clay belt (500 yards wide), then the sand-dune belt (1,000 yards wide) forming slightly higher ground on which the city is built, then marsh clay returns further to the North-West, e.g. in the city Park 7401. South-West of the river, marsh clays extend to a line from Brinkum through Huchting 6796 to Hasbergen 6298 where sandy dry terrain begins with patches of marshy clay ground along old river courses (aligned mainly North-South). A large sand-bank lies North of Woltmershauservolt 6900 on the West side of the river. Considerable portions of the river banks have been altered by port construction work, a factor not taken into consideration in this report. In the Bremen area borings show that the marsh clay is 9.8 - 16.4 ft. thick, overlying sand and gravel to a depth of 164 ft. or so.

Bremen - Braake. 6004.

Along the right bank of the Weser, the narrow sand dune belt (1 mile wide) continues from the N.W. outskirts of Bremen to Burgdamm 6509 broken only by the River Lesum. Between this sand dune belt and the river and north-west of the docks area, marsh clay forms a large tract from Mittelsburen 6204 to Sesumbrok 6107. The left bank of the Weser in this area is partly of sand, partly of clay adjacent to the river, backed by waterlogged marsh clay. Borings prove that the marsh clay is about 13.1 ft. deep, under which another 13.1 ft. of peaty clay occurs, before sand is encountered; the deposits are quite soft to a depth of 39.4 - 49.2 ft.

Braake - Farge 5312.

From the north-west outskirts of Bremen to Vegesack 6009 both sides of the river are of heavy marsh clay except for a large sand bank at Braake (west side of river) and a narrow sand bank from Niederburen 6105 to Vegesack (east side of river). From Braake to Bordenfleth 5609 the river bank has been built up artificially. Small sand patches lying on top of the marsh clay occur at Altenesch 5904 and Deichshausen 5906. At Deichshausen 6101 a sand zone extends northwards towards the Weser river along the west bank of the River Ochtum.

Downstream from Vegesack surface conditions are similar to those at Bremen. The north river bank has a narrow clay belt backed by a narrow sand dune zone on which Grohn, Vegesack, Blumenthal and Farge are situated; behind this sand zone, marsh clay appears once more and extends to the northeast, but the terrain is higher in altitude and well drained. Along the south bank of the river, marsh clay covers the river plain south-westwards to a line through Moor 5301 and Hude 4802 where fairly dry sandy ground begins. In the Vegesack area, the marsh clay is 13.1 - 16.4 ft. thick lying on sand and gravel.

F. SHEET L.3

The surface is waterlogged salt marsh clay along both sides of the river, especially to the west. Five to ten miles east of the river slightly drier sandy ground begins but even here the water table is very near the surface.

Osterstade - Wuhrden

Along this tract east of the river, marsh clay forms a north-south belt 15 miles long, 3-5 miles wide, the land surface being but 6.6 ft. above sea level. Borings at Neuenlande 5336 proves clay to a depth of 55.8 ft. with a peaty bed from 19.7 - 26.2 ft. below surface. Below 55.8 ft. sand and gravel form a 9.8 ft. thick bed lying on old firm river sands and clays which have been encountered down to 190 ft. below the surface.

West of the river marsh clay is universal except for the river banks which are sandy in places. Borings at Rodenkirchen 4835 proved 13.1 ft. of recent marsh clay, then 16.4 ft. of old marsh clay, then firm sand and clay below. At Blexen 5248 the marsh clay is probably 66 - 82 ft. thick. It is useful to note that the firm sands underlying the marsh clay are shallowest under the river banks, deeper away from the river towards the west and deepest under the river bed; and also that the artificial dykes have caused sudden changes in the surface deposits so that on one side of a dyke, there may be sand, whilst on the other, marsh clay may occur.

Bremerhaven.

The river swings eastward to the edge of the marsh clay. The town is situated on drier sandy ground but details are not available. A water table close to the surface must be expected.

Landewursten.

North of Bremerhaven the river swings westwards and a marsh clay belt forms the east bank (coastline)

G. RIVER TERRACES.

Frequent mention has been made of terraces in the Weser River Valley mainly in the hill part. No heights have been given since their determination would have meant considerable expenditure of time.

However, it is possible to summarize the position as follows:-

1. The Hilly Part above Minden

Here three terraces, an upper, a middle and a lower, have been distinguished. All three terraces increase in height, above river level, up river, more or less regularly. At Minden, the lower terrace is 9.8 ft. above the river level, the middle terrace 26.2 ft. and the upper terrace 49.2 ft. At Hann Munden the lower terrace is 6.6 ft. - 9.8 ft. above river, the middle terrace 49.2 ft. and the upper terrace 85.3 ft.

2. The Lowland Part below Minden

Here the upper terrace is usually absent or some distance away from the river, The lower and middle terraces are usually well developed except in the lower river reaches below Verden. There does not appear to be much reduction in height above river level as we go downstream. The middle terrace remains about 26.2 ft. above river level, the lower terrace about 9.8 ft. above river level.

Usually the terraces are well drained loams, sands and gravels; the higher the terrace the coarser the subsoil tends to be; but also the higher the terrace the less extensive, and the more discontinuous it becomes, since it has been subjected to wearing away for a much longer time. Loess terraces are exceptional in this respect; they are usually fine grained and equally extensive at all altitudes above the river level; they have been deposited by wind on high and low ground more or less simultaneously.

H. Sources of Information

1. Geologische Kartevan Preussen und Benachbarten deutschen Landern. Scale 1:25,000. Sheets 55/32, 26, 13, 7, 2, 1; 41/55, 4, 9, 54, 53, 52; 40/46; 23/58, 57, 50.
2. Geologische Ubersicht Karte van Deutschland. Scale 1: 200,000. Sheets 80, 99, 112.
3. Geologische Karte des Deutschen Reichs (Lepsius). Scale 1:500,000 Sheets 7 and 13.
4. "Handbuch der Vergleichendes Stratigraphie Deutschlands - ALLUVIUM" (Stoller) Berlin 1931.
5. "Beitrage zur Kenntnis des Pliocans und der diluvialen Terrassen in Flussgebiet der Weser" (Siegert) Abhand der Preuss. Geol. Landesanstalt Neue Folge: Heft 90: 1921.

APPENDIX C

DESTRUCTION AND PROTECTION OF DAMS AND LEVEES*

*Translation of "Zerstoerung und Schutz von Talsperren und Daemmen," O. Kirschmer, Schweizerische Bauzeitung, 14 May 1949, pp. 277-81 and 300-303.

DESTRUCTION AND PROTECTION OF DAMS AND LEVEES

During World War II three of Germany's dams located on the MOHNE, SORPE and EDER Rivers were attacked on the same night. This operation was carried out by the Royal Air force during the night of 16 and 17 May, 1943 as a low-level surprise attack from a height of approximately 18 m, using special heavy rotating bombs (Roll Bombs).[1] Figures 1 and 2 show the location of these works. The flood wave released by their destruction caused widespread devastation. To obtain a basis for the preparation of plans for precluding or reducing damages from such occurrences in the future, these flood waves were later carefully studied. It is believed that the results of these investigations are of sufficient general interest to be published.

1. Description of the Dams and the Damages.

A. The MOHNE Dam.

This dam was built in the period 1908-1913, from a design by E. LINK, mainly for the purpose of providing domestic and industrial water supply in RUHR area. The drainage area above the dam is 430 km^2, the average annual inflow is $240x10^6$ m^3, the reservoir capacity is $134x10^6$ m^3, and the surface area is 10.2 km^2. This gravity dam with an arched axis is 650 m long at the crest and 40 m high. (Maximum water level 32 m). The top width is 6.25 m and the base width 34 m (Figure 3).

The attack by the Royal Air Force was carried out during the period when the reservoir was completely full. On 17 May 1943 at 12:49 a.m., a bomb exploding close to the face of the dam approximately 10 m below the water surface breached the upper part of the dam. A gap 76 m wide at the top and 22 m deep developed in the center of the dam. Within the next 12 hours $116x10^6$ m^3 of water escaped through this breach. On the 16 of May 1943 the storage in the reservoir was $132.2x10^6$ m^3. It was later determined that the initial rate of flow through the gap was 8,800 m^3/sec. In the narrow MOHNE Valley this caused a surge 10 m high which caused great destruction. This surge was considerably higher than the highest flood of record, the flood of 1890. Approximately 1200 lives were lost. All buildings situated on low ground between the dam and HAGEN (approximately 65 km downstream) were either swept away or damaged. All bridges for 50 km downstream were destroyed. Eye witnesses report that the water piled up as high as 2 m on the bridges before they collapsed. The power stations, No. I located at the foot of the dam (4,800 kw output, four generating units), and No. II (300 kw, two generating units) located at the re-regulation pool at GUNNE, just disappeared. At the confluence of the RUHR and the RHINE Rivers (148.5 km from the MOHNE Valley dam) the stage rose about 4 m when the crest of the flood wave, 25.5 hours after the catastrophe, passed there. This meant that the discharge of the RHINE River increased by 1100 m^3/sec.

The effects of the rupture of the MOHNE dam were very serious because on one hand this dam was the main source for the water supply of the densely populated RUHR area, and on the other hand its rupture flooded most other water supply plants in the RUHR all the way to ESSEN and put them out of commission. A large number of towns like HAMME, HAGEN, BOCHUM and DORTMUND were without water. Also, the pump storage plant at HERDECKE on the RUHR, 60 km below the MOHNE dam, which with its 132,000 kw output is one of the most important power stations of the RHEINISCH-WESTFALISCHEN Electric Power Company (RWE), could not operate for 14 days because its power house was under 2 m of water.

B. The SORPE Dam.

Here we deal with a dam constructed in the period from 1922-1933 as an earth fill structure with a watertight concrete core wall also designed and built under the direction of E. LINK (Figure 3). The height of this dam above the valley floor is 60 m, the maximum water depth is 57 m, and crest is 700 m long. The upstream and downstream slopes at the center of the dam are 1 on 2.25 and 1 on 2.50, respectively. To make it difficult for water to penetrate the dam the upstream part is constructed of impervious material covered by a protective layer. The downstream part is constructed of pervious material to allow that water which seeps through the impervious part and the core wall to drain as fast as possible. The storage capacity of the SORPE reservoir is 81×10^6 m^3. When completely full a lake of 3.8 km^2 is created. The annual flow of water from the catchment area into the reservoir is 31×10^6 m^3.

The air attack on the SORPE dam was carried out at the same hour as the one on the MOHNE dam, apparently with the intent to cause them to fail simultaneously. <u>This earth dam however did not fail,</u> although the crest of the dam received two direct hits which created craters 12 m deep. The attacks on the SORPE dam were later repeated several times, including a concentrated attack on 16 October 1944. In all these attacks 11 hits were scored on this earth dam without causing a collapse or leakage. After the first attack, however, the water level in the reservoir was lowered a few meters as a precautionary measure.

<u>The fact that the gravity masonry dam on the MOHNE was ripped open while the earth dam across the SORPE withstood the attack is of decisive importance.</u> The effect on the RUHR area would have been of catastrophic proportions if the SORPE valley reservoir also would have run out during those early morning hours of the 17 of May 1943, and the two flood waves would have combined and superimposed themselves on each other.

C. The EDER Dam.

This dam is located at WALDECK in the vicinity of KASSEL and was, after the successful action against the MOHNE dam, the target

of the same Royal Air Force outfit. These two dams are only 80 km airline distance apart. The EDER dam is Germany's second largest dam (second only to the BLEILOCK dam on the upper SAALE in THURINGEN), and was constructed in the years 1908-1913 as a rubble masonry gravity structure. This dam stores 202×10^6 m^3 water, and when completely full creates the impressive and beautiful EDER Lake which covers an area of 11.7 km^2. The average annual inflow into the reservoir is 500×10^6 m^3. The EDER Lake augments low flows, helps control floods on the FULDA and WESER River, benefits navigation, and supplies the MITTELLAND canal with water. In addition, power is generated by the EDER dam. Immediately downstream of the dam are the power stations HEMFORTH I (13,000 kw) and II (17,000 kw) with nine generating units in all. In addition, in HEMFURTH is the pump storage plant WALDECK, which with its four turbines has a peak output of 115,000 kw, and finally there is at AFFOLDERN at the EDER re-regulation pool a small run-of-the-river power plant with a single turbine delivering 2,560 kw.

This arched masonry dam is 400 m long at the top, 48 m high and the maximum water depth is 41 m. The wall is about 6 m thick at the crown and 35 m at the base. A cross section is shown in Figure 3.

In the attack on the EDER dam which occurred at 1:20 a.m. on the 17 of May 1943, a hole of about 25 m radius (figures 4 and 5) was blasted through the dam near the left tower (as seen from the downstream side). As the breach was smaller than the one in the MOHNE dam, the time needed for the reservoir to run out was longer than at the MOHNE. The maximum discharge through this breach was computed to have been 8,500 m^3/sec, or to have been of similar magnitude as the flow from the MOHNE dam. The time, however, to empty the reservoir of 154.4×10^6 m^3 out of a total of 202.4×10^6 m^3 which were in storage at the time of the attack, extended to 36 hours.

Besides the opening which resulted from the blast, cracks and loosened sections appeared in several places. The damage at the power stations at HEMFURTH and AFFOLDERN was reported as severe. The flood wave which was able to spread easier in the much larger EDER and FULDA valley, did not have the same catastrophic effect here as it had in the narrow MOHNE and RUHR valley. The damage, however, was still large enough. The river bed of the EDER from the dam to the mouth was completely devastated, and in addition, large land areas were flooded and covered with silt. The retaining dike of the re-regulation pool showed large crevices and wash-outs. The rapid dropping of the water level in the EDER lake caused large slides in four places along the shore. The locks of all seven dams on the canalised FULDA between GUNTERHAUSEN and HANNOVERISCH-MUNDEN were silted in and partly washed out. Manifold damage was caused on the weirs and gates. The flood wave caused a heavy bedload movement which made it necessary to dredge 30,000 m^3 to restore the original conditions on the FULDA. This bedload movement continued in the WESER downstream of HANNOVERISCH-MUNDEN causing shoals which had to be removed by further dredging (app. 5,000 m^3). In addition, about 1,000 spur-dikes on the WESER were either

destroyed or damaged. The shore line of both the FULDA and WESER heavily damaged. On the WESER alone 5.5 km of shore protection had to be rebuilt.

II. Flow of the MOHNE dam floodwave.

The reconstruction of the movement of the flood wave after the MOHNE dam catastrophe was difficult, due to the destruction or damage of most stream gages on a long reach of river below the dam. Most of the gages which were left in operation were incapable of measuring the unusually high stages. For this reason only few definite gage readings are available in the MOHNE and upper RUHR valley. Regular and true measurements were only possible below the town of HAGEN in the middle part of the RUHR valley. However, the marks which the flood left behind made it possible to determine the maximum stages without gage readings. The determination of the time of travel which the flood wave traced was much more difficult. For this it was necessary to rely on the reports of eye witnesses. As it is well known that such reports may be very questionable, a conscientious and critical evaluation of all eye witness reports was performed by the competent authority, Water Resources Control Office (Wasserwirtschaftsamt) at HAGEN. The results of this investigation are presented in table 1 and on figures 6 and 7.

A. The flow from the dam.

At the time of the attack the reservoir contained 132.2 $\times 10^6$ m^3. Regular observations on the reservoir gage were made only after the general agitation and confusion was somewhat reduced at 6 a.m. The gage readings obtained at the time of the attack (12:49 a.m.) and after 6 a.m. are shown in figure 6, and were connected by a curve based on the assumption that the flow had been continuous and that the initial size of the break in the dam was equal to its final size.

The time t and the time difference Δt (columns 1 and 2 of table 1) were determined from the reconstructed curve of the storage volume V_1 as a function of time for points of even 10×10^6 m^3 volume (column 3 of table 1). A definite amount of water was retained in the HEVE and STOCKUM forebays, two sub-reservoirs of the MOHNE reservoir, connected with the main basin only by small gates. Column 4 of table 1 takes this into consideration.

The discharge $Q = f(t)$ can be determined either as $Q = \Delta V/\Delta t$ (column 7) or as $Q = dv/dt$ (column 8) the slope of the tangent to the curve $V = f(t)$ at the time t. By this method the maximum discharge $Q_{max} = 8{,}800$ m^3/sec was obtained. The discharge however dropped rapidly. At 6 a.m. or 5 hours after the dam break, it was still 2,000 m^3/sec and three hours later 1,000 m^3/sec (figure 6). It can be assumed that by 12 o'clock noon the outflow for practical purposes was complete.

B. The flood wave timing in the MÖHNE and RUHR valley.

The results determined by the Water Resources Control Office at HAGEN are shown graphically on figure 7. The curves represent the theoretical course of the flood wave. In reality these curves are less regular, because the wave is dependent upon the changing shape of the valley. Where the valley widens the wave has a chance to spread and its progress is therefore retarded. This was the case especially at the three RUHR lakes. These are the HENGSTEY Lake at HAGEN (1.6 km^2 area and $2.8x10^6$ m^3 storage), the HARKORT Lake (1.4 km^2 area and $3.3x10^6$ m^3 storage), and the BALDENY Lake on the south edge of the city of ESSEN (1.4 km^2 area and $9x10^6$ m^3 storage). The BALDENY Lake was completely empty at the time of the accident in the MÖHNE Valley. This lake was emptied as a protective measure against air attacks (to make orientation difficult). The HENGSTEY and HARKORT Lakes were full but were immediately emptied when the facts of the catastrophe became known.[2]

To what an extent the BALDENY Lake reduced the approaching flood wave can be seen from the fact that the high water level downstream was lower than the catastrophic flood of 1890, while upstream it was higher. The inflow into BALDENY Lake was about 2,500 m^3/sec, a flow which theoretically could be held back for one hour. The time of the arrival of the flood wave head that is the beginning of the rise, and the time of the passing of the crest, are shown for the entire reach from the MÖHNE Valley to the mouth of the RUHR about 150 km long by curves 1 and 2 of figure 7. The time scale on the left of the figure should be used for these two curves only. It is natural that the lag between the beginning of the rise and the passing of the crest increases with increasing distance. At the mouth of the RUHR this lag was 6 hours.

In addition, figure 7 shows the velocity of the wave at its head (curve 3) and at its crest (curve 4). The velocities were determined from curves 1 and 2 according to the equation $C = dl/dt$ which is represented as tangents to these curves. Table 2 shows some of the important values.

C. Stages and Discharges.

In the MÖHNE valley the stages exceeded the previously accepted maximum, the flood of 1890, by an average of 3 to 4 m. In the vicinity of HAGEN, about 65 km below the dam, the stage exceeded the 1890 flood by 2 m, and at the entrance into BALDENY Lake by still 0.50 m. Below the lake the water level approached the 1890 stage within 0.50 m. It was determined that especially high stages occurred wherever the valley became narrow or where bridges and similar structures obstructed the flow.

The measured stages were converted into approximate discharges Q by the use of extrapolated rating curves, in the entire MOHNE and RUHR valley. Curve 5 in figure 7 shows the result. It can be seen that a relatively fast flattening of the flood wave took place. In the approximately 150 km long reach from the origin to the confluence of RUHR and RHEIN, the peak discharge Q changed from 8,800 m^3/sec to 1,840 m^3/sec. Of this amount 740 m^3/sec came from the normal RUHR flow while 1,100 m^3/sec can be charged to the flood. This was determined by gage observations on the RHINE River at DUISBURG just downstream from the mouth of the RUHR.

III. Flow of the EDER Dam floodwave.

Figure 8 shows graphically some of the phenomenas associated with the failure of the EDER Dam, compiled from investigations made by the Waterways Bureau (WASSERSTRASSENDIREKTION) at HANNOVER. This figure presents basically the same picture as the one representing the failure of the MOHNE dam. It should be noticed that the peak discharge values vary only slightly at both dams (MOHNE Dam Q_{max} = 8,800 m^3/sec, EDER Dam Q_{max} = 8,500 m^3/sec). The duration of the outflow, however, is considerably different. While the MOHNE Dam was empty in 12 hours, the 1.4 times as great water volume at the EDER Dam required, thanks to the smaller breach, 48 hours to flow out. Figure 9 represents data on the flow of the floodwave created by the failure of the EDER Dam, in the EDER, FULDA AND WESER valley. The floodwave flattened out rapidly because the water had sufficient space to spread. At 75 km downstream from the dam the stages were below the maximum flood of record (Jan. 1841). At the gage at INTSCHEDE near BREMEN (425.6 km from the dam) the discharge was only 665 m^3/sec. and about 58×10^6 m^3, that is, 1/3 of the amount that escaped from the reservoir was held by the valley storage of the floodplain above this point.

The velocity of the floodwave too was less here than in the MOHNE valley.

These computed values were verified in August 1946 when a floodwave, intentionally released from the rebuilt EDER Dam, was observed throughout its travel. The mean velocities determined in this test for the reach from the dam to HANNOVERISCH-MUNDEN, a distance of 94.4 km, were 2.00 m/sec for the head and 1.31 m/sec for the crest of the floodwave. These values are sufficiently close to the values shown in table 3.

One of the most urgent, simplest and cheapest safety measures that can be devised against the effects of dam failures is a careful study of the travel of intentionally released floodwaves. This would not only yield information regarding the speed of events during an actual dam failure, but would also point out points of probable danger in time to develop a safety plan and carry out protective measures.

IV. Air Attacks on Canals.

Following the summer of 1944, navigation and power canals became the targets of air attacks. Especially those stretches of canals were bombed where it was either possible to cause flooding, due to the fact that the canal level was higher than the surrounding terrain, or where structures like bridges, locks, or canal intersection, whose reconstruction is difficult or time consuming, could be damaged or destroyed. An especially worth-while target was the vicinity of DATTELN (figure 1) where several canals join.

A. The DORTMUND-EMS Canal.

This canal is one of the most important waterways in Germany. It connects the RUHR area with the North Sea, has a depth of 3.20 m and an average width at the water level of 40m. The channel sides slope in the upper part 1 on 2.5, in the lower 1 on 4. The bottom is 20 m wide and slightly sloped at 1 on 40. Where the canal runs above the surrounding terrain, the dikes have a top width of 3.50 m and a landside slope of 1 on 1.5. This canal was attacked 6 times in the vicinity of DATTELN from 23 September 1944 to the end of the war. The damages were so extensive that only in March 1946 navigation was provisionally reestablished. The first attack caused a dike failure through which a 30 km long reach with a water content of $3x10^6$ x m^3 ran dry.

B. The WESEL-DATTELN Canal.

The dikes along this canal have a top width of 8.00 m, landside slopes of 1 on 3 and waterside slopes of 1 on 3 or 1 on 4. The water depth is 4.20 m. This dike was damaged by bombs in one place so badly that 2.5×10^6 m^3 of water poured out washing 30,000 m^3 of soil away.

C. The DATTELN-HAMM Canal.

This waterway was hit by more than 100 bombs in a place where the dike crests rise 6 to 7 m above the surrounding terrain. The top width of the dike is 3.50 m and the water and land side slopes are 1 on 3 and 1 on 2, respectively. By this bombing the water was released and 20,000 m^3 of soil were washed away.

The high dividing levee between the canal and the river LIPPE, a levee with a top width of 5 to 8 m and slopes towards the river of 1 on 2, also received more than 100 hits. However, it did not collapse and withstood a flood on the LIPPE river without failure in spite of the many weakened places.

D. The RHEIN-HERNE Canal.

In this case we were successful to close each breach opened by the fall of heavy bombs. Dike failures which would have emptied the canal did not occur.

E. The Canal "MITTLERE ISAR."

This 53.5 km long canal, owned by the power company "BAYERNWERK AG" branches from the ISAR river at the northeast edge of the City of MUNCHEN (figure 11), and carrying at the intake a maximum flow of 125 m^3/sec, supplies four power stations – FINSING, AUGKIRCHEN, EITTING AND PFROMBACH with a combined output of 82,500 kw. Air attacks were carried out against the upper reach on the 9 of June and the 11 and 13 of July 1944. A chart showing the bomb hits was drawn by the construction office of the "BAYERNWERK AG" and is shown on figure 13. The canal did not leak out in spite of 60 to 70 hits. The levee fill consisting of gravel and clay closed its own breaches by slumping. Even the power station continued to operate on a reduced scale (1/4 to 1/3 of normal output). Figure 10 shows a damaged section of the ISAR canal where the concrete lining of the slopes can still be seen. The repair work took one-half year.

The experience gained from air attacks on canals has taught us that the usual dike top width of 3.5 m is too small. However, the example of the MITTLERE-ISAR canal shows that in spite of this, the dike failure is not inevitable. It is recommended that the crests be enlarged to about 6 m thickness. The failure of the levee on the WESEL-DATTELN canal, in spite of its crest thickness of 8 m, proves that a thickness of 6 m can still be insufficient. It is most likely impossible, for economic reasons, to increase the top width of the dikes above 6 m. Complete safety is not obtained, but for most instances, the safety is sufficient, especially if the fill material is properly selected. It would be asking too much to require a levee cross section which would preclude all dangers. If such an idea is carried through, one soon reaches dimensions which can not be technically or economically justified.

V. MODEL TESTS

During studies made in 1935 by the Saxonian Waterways Construction Bureau in DRESDEN regarding a storage basin near PIRNA (figure 14), the question as to the extent of damages which would be caused by a destruction of the earth dam of the basin, was raised. This basin was to be built for the purpose of facilitating navigation on the ELBE during low flows, and was to have a content of 120x10^6 m^3. An answer was required especially regarding the effect of a floodwave on the City of DRESDEN, located only 17 km from the basin, in case of a dam failure. As there was no experience to draw from, the author of this paper was commissioned to find the answer to these questions by model

tests. The tests showed that a flood wave originating at the PIRNA basin would flatten out comparatively fast because sufficient space exists between PIRNA and DRESDEN for overbank flow. This result was confirmed by the phenomenas observed at the failures of the MOHNE and the EDER dams. A sufficiently good quantitative similarity was also found. (3) The model tests showed further that the stages in the City of DRESDEN during the passage of such a flood wave would not be appreciably higher than the stages during the catastrophic flood of 1845, and the old bridges with their comparatively small openings (figure 15) were just large enough to pass such a flood. The effects of damage of the dam crest are more serious. The model tests showed that an earth dam is beyond all help if water from the basin, following a penetrating damage can leak out, even if it is in the beginning only a thin and intermittent jet. The water then begins to scour and gnaws a comparatively narrow, steadily increasing in depth, slat in the dam. This process does not stop until the entire reservoir is empty. The different phases of such a dam failure in the model are shown on figures 16 A through G. To make the model conditions as similar as possible to nature, blasts of one or more 200 gram charges (mostly TNT) were set off on a dam model 3 m high and 2 m wide at the top, which was erected in the open. The fill material was non-binding sands with from 0.02 to 2 millimeter grain size. 3The proportionality law of explosions is given by the formula $t = a\sqrt[3]{L}$ or $t^3 = a^3L$, in which t is the depth of the crater in meters and L is the amount of explosives in kilograms. This shows that eight times as much explosives are necessary to double the depth of the crater. The factor "a" is dependent on the soil condition and in this case was found to be 0.73. It was also determined that "a" is little dependent on the type of explosive used. It was assumed in all tests that the explosive occurred at optimum depth (about 0.8t) and that a crater with the natural slope of 36° (or an overall angle of 108°) was found. The proportionality law of explosions was checked and confirmed for charges up to 1,000 kg. The values for light sandy soils are given in table 4 (status 1945).

All model tests, regardless of their scale, showed conclusively that any leakage, even an insignificant one, represents primary danger because it leads without fail to a dam break, except if it is possible to stop the flow at the damage point immediately.

This points the way towards the development of earth dams of such form and size that would make the probability of or damage causing a leak a small one. This means thicker dams than before, especially at the top, and flatter slopes. For the earth dam of the proposed PIRNA reservoir, which was to be about 30 m high, the crest width was changed from 10 to 30 m, and the slope from 1 on 4 to 1 on 2.5, as a result of these model tests. However, this design has not been executed. These dimensions appear unreasonable. However, they are not if you compare them with the Russian earth dams on the WOLGA. The dam at UGLITSCH is at the normal water surface elevation 60 m thick, and the earth dam near RYBINSK is even 147 m thick. It must be remembered that there are in the "RYBINSK SEA" nearly 25×10^9 m^3 of water which in a dam failure would cause an immense flood.

With the crater shape and the scale relation determined by the model tests, all further work can be done graphically. Figure 17 shows this as applied to the dam at PIRNA under the assumption that 11 and 9-1,000 kg chargew respectively were simultaneously exploded at optimum depth in the dam crest. In the first case (a) the dam would be cut through completely while in the second case (b) several humps would remain which the water surge created by the explosion would scour away. The model tests confirmed that the assumption was correct. It is assumed that all charges are simultaneously detonated. If this is not the case, the effect will be considerably reduced, because the late blasts would partially fill in the craters blown by the early ones. This is the reason why the earth dam across the SORPE River withstood 11 heavy bomb blasts. The case of the MITTLERE ISAR canal shows that a bomb mosaic must not necessarily cause a dam failure.

VI. Discussion and Conclusion

The catastrophies which occurred in the MOHNE and EDER valleys during the late war, and the failures of the levees along several canals, point up the fact that in the planning of hydraulic structures protection against intentional destruction needs more study today than ever before. Complete and absolute protection is impossible especially because in the progress of engineering the meaning of safety is a continuously changing one. However, as most hydraulic structures, especially dams, are long-term projects which fulfill their purpose for a generation or more, protection is very difficult because it is impossible to foresee the development of engineering for centuries ahead. It is the duty of every responsible engineer to plan ahead safety measures, and continue to improve them, which protect against foreseeable dangers and are possible, sensible and economical.

In the case of dams and levees the following conclusions were reached:

1. Earth dams provide greater protection against intentional destruction than do masonry dams. Whenever it is possible to erect an earth dam in place of a masonry one, this possibility should be explored. Buttress dams are especially vulnerable.

2. In an emergency it is usually sufficient to lower the water level a few meters to give a fair degree of protection to both earth and masonry dams.

3. It appears that in the future, larger cross sections than are normal today, at least near the top, will be necessary on both earth and masonry dams. To the considerations of design used up to now, such as statics and economy, a new one, protection against willful destruction, must be added.

4. The most important step in protecting earth dams is leak proofing. Once water has found its way to the downstream or land side of a dam, an embankment failure cannot be averted. The process of destruction once begun, continues automatically. Relief is possible only in the earliest phases.

5. Floodwaves created by dam failures may have catastrophic effects in narrow valleys and near flow obstructions. In wider valleys where the water can spread, the crest of the floodwave flattens out rapidly and soon loses its destructive force. In the RUHR areas artificial lakes helped to reduce the flood created by the failure of the MOHNE dam. Storage basins like these will prove themselves helpful in many instances.

6. Safety can be improved by releasing trial floodwaves from dams, to discover hidden danger sources in advance and to institute timely, correct protection measures.

7. Model tests have shown themselves as valuable, maybe even an indispensable aid in the design of earth dams and levees in connection with their safety against intentional destruction. It also is believed that model tests would help to judge the safety of masonry structures against such destruction.

Footnotes:

1. See also "Grundsatzliches zur Wahl des Staumauertyps fur grosse Staubecken" SBZ 1948, Nr. 11, page 150.

2. The warning system operated excellently during the failure of the MOHNE dam. Villages and towns in the MOHNE and RUHR valley were informed of accident in the shortest possible time. The many fatalities, especially in the town of NEHEIM, occurred because the population did not grasp the seriousness of the catastrophe.

3. The main difficulty in reproducing a flood flow in a model is the reproduction of the roughness in the flood plain. This is only possible when sufficient and accurate data are available regarding the natural conditions.

TITLES AND GLOSSARY OF TABLES AND FIGURES

Tabelle 1.	Table 1
UHRZEIT am 17. Mai 1943	Time on the 17th May 1943.
Zeitdifferenz in Sekunden	Time interval in seconds.
Inhalt des Staubeckens in Mio m^3	Content of reservoir in millions cubic meters.
Differenz in Mio m^3	Change in millions cubic meters.
Ausgeflossenes Wasservolumen in Mio m^3	Water volume discharged in millions cubic meters.
Sekundlich ausgeflossene Wassermenge in m^3/sec.	Discharge in cubic meters per second.

Tabelle 2. (Table 2) Velocity of the wave head and crest in the MÖHNE and RUHR Valley in meters per second.

Stelle	Location
Sperre	Dam
Mundung in den Rhein	Confluence with RHEIN
Durchschnittswert	Average value
Wallenkopf	Wave head
Wellenscheitel	Wave crest

Tabelle 3. (Table 3) Velocity of the wave head and crest from the EDER dam in meters per second.

Stelle)
Sperre)
Wellenkopf) See glossary for table 2
Wellenscheitel)

bei Bremen

Tabelle 4. (Table 4) Blast effects in light sandy soil.

Sprengladung	Explosive charge
Trichter	Crater
Tiefe	Depth
Modellversuch	Model test

Bild 1. (Figure 1) Location map of MOHNE and SORPE dam and the navigation canals in the RUHR area. Scale 1:800,000

Talsperre	Dam
Kanal	Canal
See	Lake

Bild 2. (Figure 2) Over-all map of the EDER-FULDA-WESER Rivers and MITTELLAND canal drainage area. Scale 1:3,000,000

Bild 3. (Figure 3) Cross-sections through the MOHNE, SORPE and EDER dam. Scale 1:3000

Talsperre	Dam
Schutzschichte	Protective layer
Mittel	Mean
Schuttung aus dichtem material	Fill of impervious material
Beton-Dichtungskern	Concrete core
Schuttung aus material mit starkem Gehalt an Kies, Geroll und steinbruchabfall gewalzt.	Fill material containing much gravel, rubble and quarry spoils, rolled.

Bild 4. (Figure 4) Breach in the EDER dam.

Bild 5. (Figure 5) EDER dam after destruction. Upstream face

Bild 6. (Figure 6) Flow from the MOHNE dam reservoir.

Volumen	Volume
Uhrzeit	time
Secundliche Wassermenge	Discharge
Sekundliche Abflussmenge	Discharge
Zeitpunkt des bruches der sperre	Time of the dam failure
Inhalt des Staubeckens	Content of the Reservoir
Gesamtes ausgeflossenes Wasservolumen	Total water volume discharged
Beobachtungen am Pegel des Stausees	Observations on the reservoir gage

Bild 7. (Figure 7) Floodwave at the breach of the MOHNE dam; timing, velocity and discharges.

Uhrzeit T (Stunden)	Time t (hours)
Entfernung L von der MOHNE-Talsperre in km	Distance L from MOHNE dam in kilometers
Sekundliche Abflussmenge Q m^3/s in MOHNE-u Ruhrtal	Discharge Q cubic meters per second in the MOHNE and RUHR valley
Schnelligkeit C in m/s	Velocity C in meters per second
Beobachtete Werte fur die Kurven 1 u 2	Observed values for curves 1 and 2
Beginn des Steigens (Wellenkopf)	Begin of rise (wave head)
Wellenscheitel	Wave crest
Bruch der Staumoner	Failure of masonry dam
Schnelligkeit des Wellenkopfes	Velocity of the crest
Secondliche Abflussmenge	Discharge
Schnelligkeit des Wellenscheital	Velocity of the crest
Pagel	Gage
P.	Gage
Schleuse	Gate

Bild 8. (Figure 8) Flow from the EDER Valley reservoir

(See glossary to figure 6)

Bild 9. (Figure 9) Floodwave in the EDER, FULDA and WESER rivers due to the break of the EDER dam.

Gesamte Abflussmenge beim Bruch der Speere	Total volume discharged by the dam failure
Hochstes bekanntes Hochwasser vom Jan 1841	Highest known flood, Jan. 1841
Hochwasserwelle mach dem Bruch der EDER talspere	Floodwave following the failure of the EDER dam

Bild 10. (Figure 10) Damages to the MITTLERE ISAR canal.

Bild 11. (Figure 11) Situation plan of the ISAR canal; 1:750,000

Wehr	Weir
Kanal	Canal
K.W.	Power Station
Ausgleich-Weiher	Re-regulation pool

Bild 12. (Figure 12) Cross section through the levee in the area shown in figure 13.

Betonschale als Cichtung von Boschung	Concrete liner for waterproofing of slopes and invert, average 20 centimeter thick.

Bild 13. (Figure 13) Bomb hit diagram from the air attacks on the MITTLERE ISAR canal below MUNCHEN, Plan 1:17,500

Wehr und Einlaufbauwerk	Weir and intake structure
Brucke	Bridge
Bild 14. (Figure 14)	Situation plan of the proposed reservoir at PIRNA above DRESDEN
Oberfloche	Surface area
Inhalt	Content

Bild 15. (Figure 15) Model for the flood flow tests from PIRNA reservoir.

Bild 16. (Figure 16) a through g. Model test of an earth dam failure. Height of the model dam 3 m. top width 2 m.

Bild 17. (Figure 17) Dike for PIRNA with different blast craters. Cross-section . Scale 1:1200.

Elf	Eleven
Neun	Nine
Ladungen	Charges
Trichter	Crater
Durchmesser	Diameter

NOTE: All geographic and other names are shown in capital letters. The German spelling is used so that they match the maps presented.

TABLE 1 - (MOHNE DAM FLOODWAVE DATA)

Time on 17 May 1943	Time Interval (Sec)	Volume of Reservoir (mill.m^3)		Change in Volume (mill.m^3)	Total Volume Discharged (mill.m^3)	Discharge in cubic meters per second	
t	t	V_1	V_2	V	V	Q	Q
1	2	3	4	5	6	7	8
0:49		132.2	132.2		0		8800
	1380			11.76		8520	
1:12		120	120.44		11.76		8060
	1080			8.42		7800	
1:30		110	112.02		20.18		7040
	1320			8.55		6480	
1:52		100	103.47		28.73		6480
	1440			8.52		5920	
2:16		90	94.95		37.25		5560
	1680			9.50		5660	
2:44		80	85.45		46.75		5040
	2040			9.47		4640	
3:18		70	75.98		56.22		4350
	2460			9.69		3940	
3:59		60	66.29		65.91		3600
	3180			10.00		3140	
4:52		50	56.29		75.91		2780
	4020			10.00		2490	
5:59		40	46.29		85.91		1990
	6000			10.00		1670	
7:39		30	36.29		95.91		1530
	12300			10.00		813	
11:04		20	26.29		105.91		556

TABLE 2 - VELOCITY OF THE WAVE HEAD AND CREST IN THE MOHNE AND RUHR VALLEY

Location	Dam (m/sec)	Confluence with RHEIN (m/sec)	Average value (m/sec)
Wave Head	7.36	1.445	2.88
Wave Crest	4.15	1.195	1.89

TABLE 3 - VELOCITY OF THE WAVE HEAD AND CREST FROM THE EDER DAM

Location	Dam (m/sec)	Bremen (m/sec)
Wave Head	2.39	1.22
Wave Crest	1.28	1.08

TABLE 4 - BLAST EFFECTS IN LIGHT SANDY SOIL

Explosive charge	(kg)	0.2*	100	250	500	1000
Crater Depth	(m)	0.43	3.4	4.6	5.8	7.3
Crater Max. Diameter	(m)	1.2	9.4	12.7	16.0	20.0

*Model Test

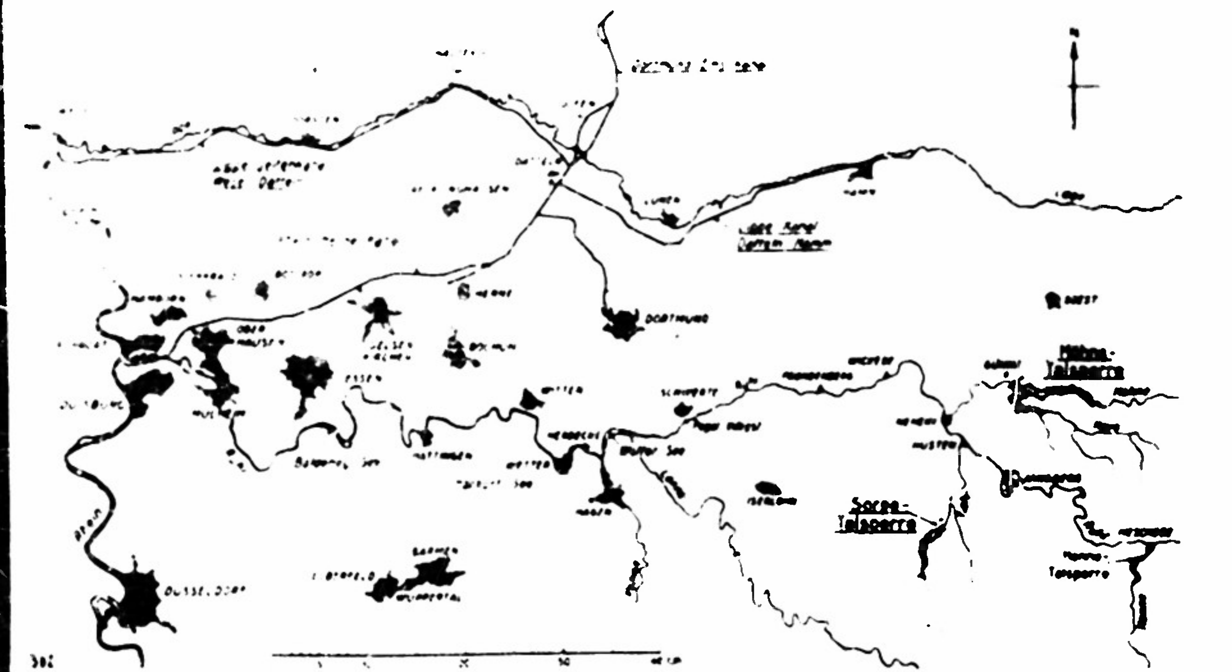


Figure 1 Location map of MOHNE and SCOPE dam and navigation canals in the RUHR area Masstab 1 : 800000

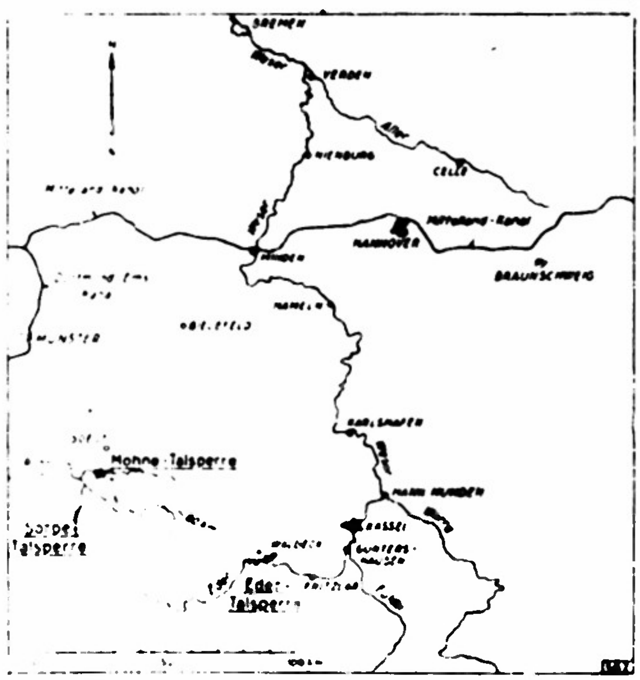


Figure 2 Over-all map of the EDER-FULDA-WESER Rivers and MITTELAND canal drainage area.

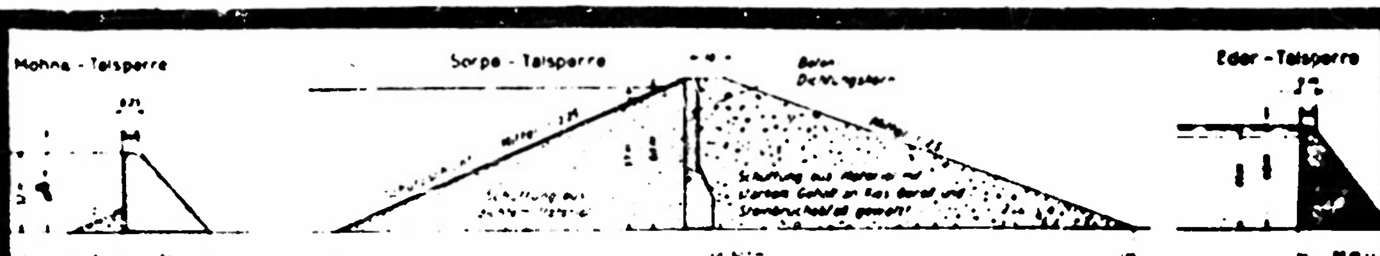
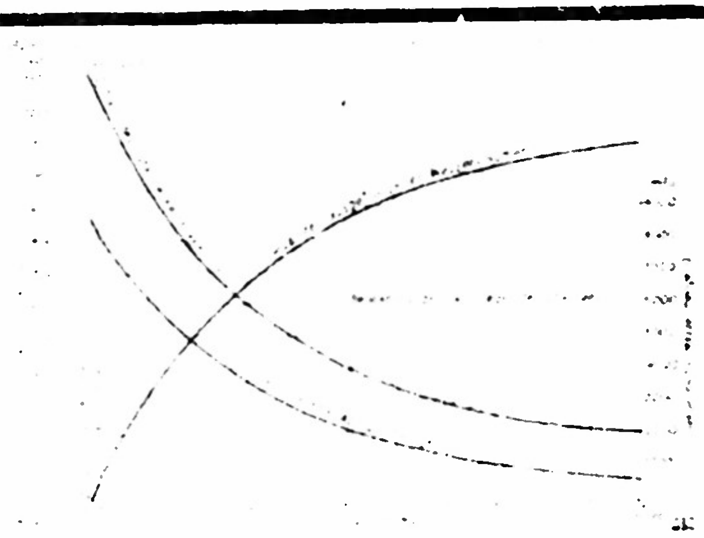


Figure 3 Cross-sections through the MOHNE, SORPE and EDER dam. Scale 1:3000



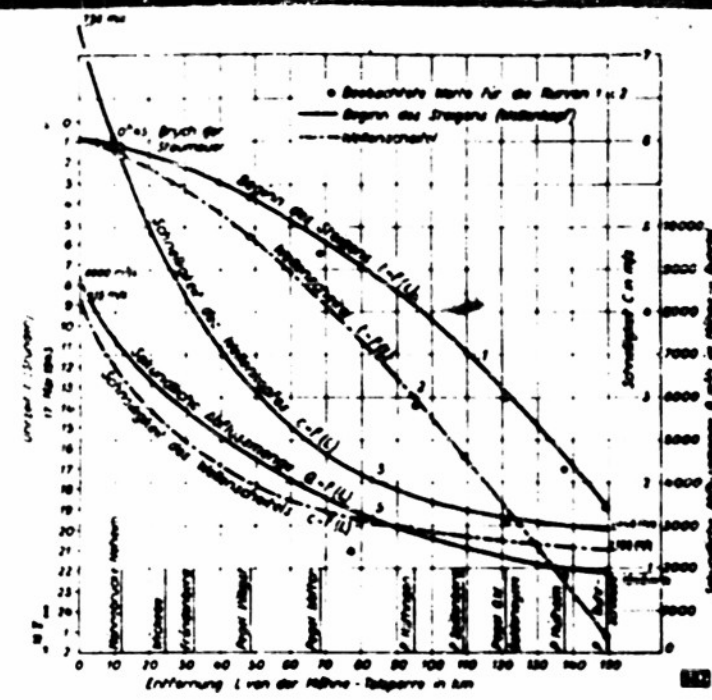


Figure 7 Floodwave at the breach of MOEHNE dam; velocity and discharge.

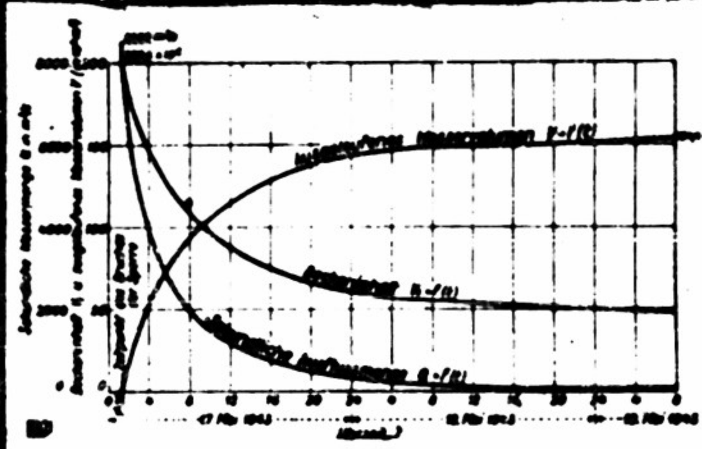


Figure 8 Flow from the EDER Valley reservoir.

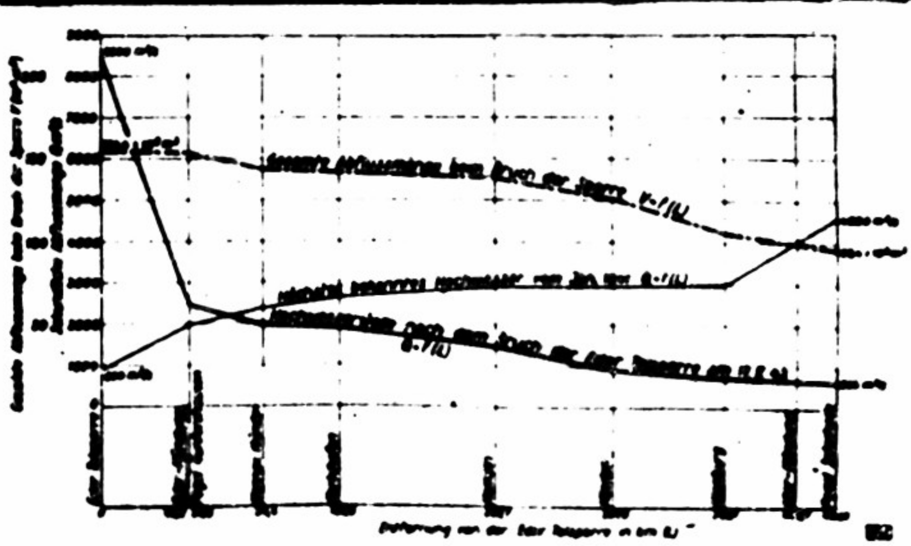


Figure 9 Floodwave in the EDER, FULDA and WESER Rivers due to the break of the EDER dam.

Figure 10   Damage to the MITTLERE ISAR canal.

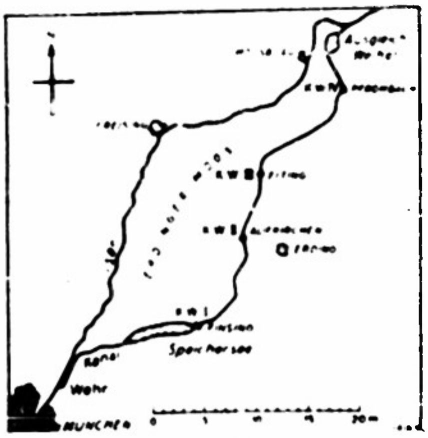


Figure 11   Situation plan of the ISAR canal.

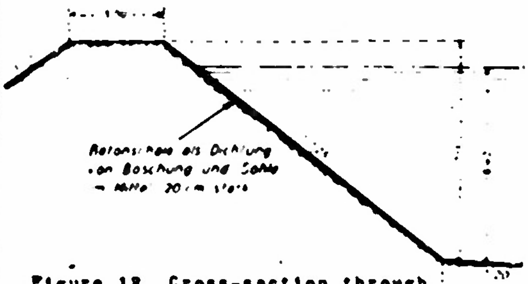


Figure 12   Cross-section through the levee in the area shown in figure 13.

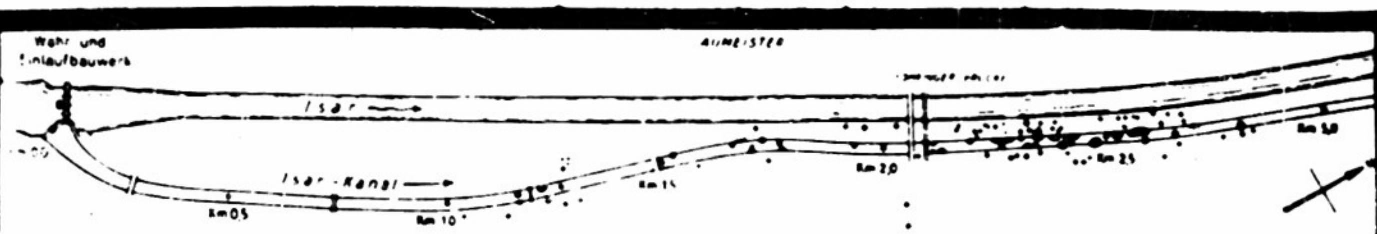


Figure 13   Bomb hit diagram from the air attacks on the MITTLERE ISAR canal below MUNCHEN. Plan 1:17,500

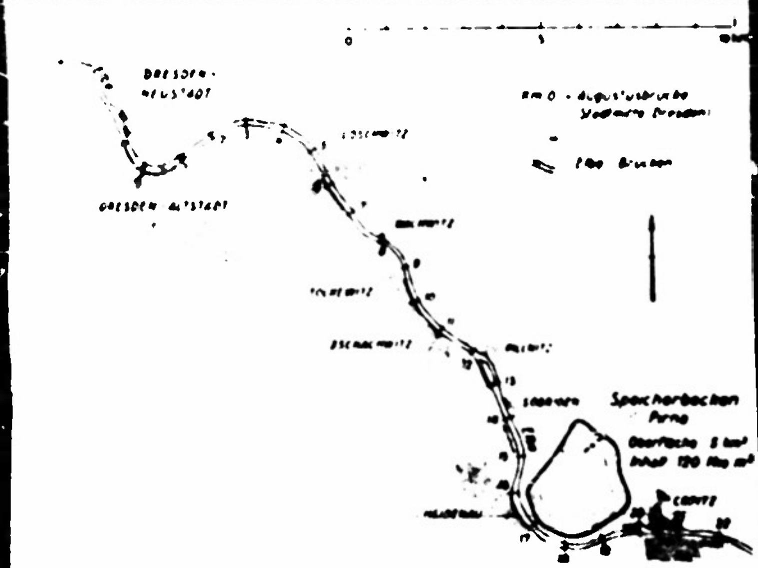


Figure 14 Situation plan of the proposed reservoir at PIRNA above DRESDEN.

Figure 15 Model for the flow tests from PIRNA reservoir.